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THE PREDICTION OF RESISTANCE CHANGE USING SMALL MODELS

DAVID W. TAYLOR NAVAL SHIP  
RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084



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THE PREDICTION OF RESISTANCE CHANGE  
USING SMALL MODELS

by

Steven C. Fisher

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SHIP PERFORMANCE DEPARTMENT

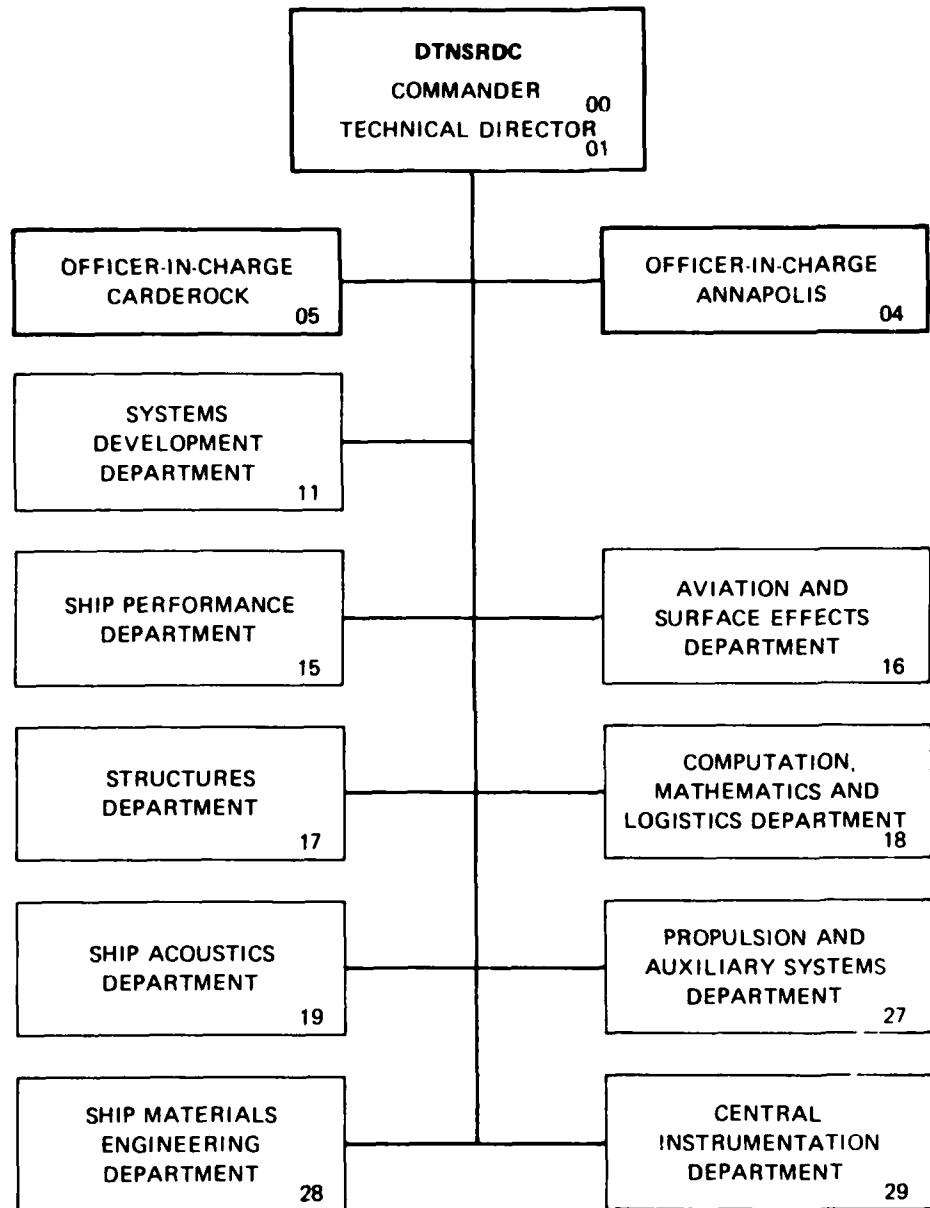
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obtain a comparison with the small model results at DTNSRDC. The results show that the small model resistance trends compare well with the large model resistance trends. The resistance of the small CVV-B model was found to be within one percent of the corresponding results from DL/SIT.

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## NOMENCLATURE

		<u>Units*</u>
$C_A$	Correlation allowance	-
$C_F$	Frictional resistance coefficient, $R_F/l_2 \rho SV^2$	-
$C_R$	Residuary resistance coefficient, $R_R/l_2 \rho SV^2$	-
$C_{SD}$	Stud drag coefficient, $R_{SD}/l_2 \rho SV^2$	-
$C_T$	Total resistance coefficient, $R_T/l_2 \rho SV^2$	-
$\Delta C_{TM}$	Difference in the total resistance coefficient between models with and without studs	-
$F_n$	Froude number	-
$1+k$	Hughes form factor	-
$L$	Length	$L$
$R_F$	Frictional resistance	$ML/T^2$
$R_R$	Residuary resistance	$ML/T^2$
$R_{SD}$	Stud drag	$ML/T^2$
$R_T$	Total resistance	$ML/T^2$
$S$	Wetted surface	$L^2$
$V$	Speed	$L/T$
$\rho$	Water density	$M/L^3$

## ABBREVIATIONS

DL/SIT	Davidson Laboratory of the Stevens Institute of Technology
DTNSRDC	David Taylor Naval Ship Research and Development Center
SCS	Sea Control Ship
USNA	United States Naval Academy

\* $L$  = length,  $T$  = time,  $M$  = mass

## SUBSCRIPTS

M	Model
S	Ship

## ENGLISH/SI EQUIVALENTS

1 degree (angle)	= 0.01745 rad (radians)
1 foot	= 0.3048 m (meters)
1 foot per second	= 0.3048 m/sec (meters per second)
1 inch	= 25.40 mm (millimeters)
1 knot	= 0.5144 m/s (meters per second)
1 lb (force)	= 4.448 N (Newtons)
1 lb (force) - inch	= 0.1130 N m (Newton-meter)
1 long ton (240)	= 1.016 metric tons, or 1016 kilograms
1 horsepower	= 0.746 kW (kilowatts)

## ABSTRACT

A series of resistance experiments were performed at the David Taylor Naval Ship R&D Center (DTNSRDC) to determine if the trends in resistance of a group of small models having somewhat similar hull forms compare well with the trends in resistance of a group of large model geosyms. Three variants of the CVV aircraft carrier were selected for these experiments; the large models represented a scale ratio of 31.435 (8.34 m), and the small models represented a scale ratio of 144 (1.82 m). One of the small models, CVV-B, was evaluated experimentally at Davidson Laboratory of the Stevens Institute of Technology (DL/SIT) to obtain a comparison with the small model results at DTNSRDC. The results show that the small model resistance trends compare well with the large model resistance trends. The resistance of the small CVV-B model was found to be within one percent of the corresponding results from DL/SIT.

## ADMINISTRATIVE INFORMATION

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## INTRODUCTION

An experimental investigation was undertaken at DTNSRDC to determine if the trend in resistance change, due to small changes in hull shape, could be predicted correctly with the use of small size surface ship models.

Large models, sometimes more than 9.1 m(30 ft) in length, are in standard use at DTNSRDC for ship model experiments. The model hull size is determined from propulsion experiment requirements. It is our experience that model propellers smaller than 0.2 m (8 in.) in diameter are inadequate to model full scale flow conditions. The effect of Reynolds Number is too severe, preventing accurate full scale powering prediction. Thus, the hull model is built to a scale ratio that results in a model propeller diameter larger than 0.2 m(8 in). The resulting model lengths vary from 5.5 m (18 ft) to over 9.1 m (30 ft).

<sup>1</sup>References are listed on page 13.

These hull models are also used for resistance experiments.

Having a large model for resistance experiments has the advantage of obtaining a more accurate geosym of the full scale hull than with a smaller model, with a given manufacturing tolerance, and the difficult problem of simulating turbulence on the model is also mitigated. The use of large models however, to investigate the effect of minor changes in hull form on hull resistance is not practical in terms of time and cost.

The need to provide experimental information on the trend of change in resistance due to changes in hull shape during the design of a new class of surface ship often arises. The use of small models in exploring the resistance trends with changes in hull form would provide a solution. The investigation described herein is aimed at exploring the potential use of small models in a small towing tank for the purpose of predicting resistance trends with small changes in hull geometry.

Small ship models are used by several ship model basins for resistance experiments such as the Davidson Laboratory of the Stevens Institute of Technology (DL/SIT) and the United States Naval Academy (USNA).

The experience of DL/SIT is adopted in this investigation to explore the trends in resistance of small models versus large models. The interest here is not in absolute values obtained, but in trends due to changes in hull form. The historical data base at DTNSRDC, used in the prediction of full scale resistance of ship hulls, which includes model-full scale correlations, was established for large models. Thus, it is not the purpose of this investigation to establish a (new) small model-to ship correlation, but to investigate the possibility of using small models to predict trends in resistance. The trends in the change in small model resistance will be compared with those of standard (large size) models.

The CVV aircraft carrier hull form variants were selected for this project because three 8.34 m (27.36 ft) long CVV models were available from previous projects. Three 1.82 m (5.97 foot) geosyms of the 8.34 m models were built to represent the small models. The three CVV hulls are designated as CVV-A, CVV-B, and CVV-D.

One of the small models, CVV-B, was built and its resistance performance evaluated experimentally at DL/SIT. This allowed us to compare our results of the small CVV-B model to the results of the same model from a model basin with an extensive background in small model experimentation.

The small bare-hull model experiments were performed in the 140 Foot Basin at DTNSRDC, and the large bare-hull model experiments were performed in the Deep Water Basin at DTNSRDC. Previous resistance experiments with the large models were performed with the models fully appended; no previous bare hull resistance data existed. An additional series of experiments with the small models were performed in the Deep Water Basin to verify the small model resistance results from the 140 Foot Basin experiments. However, because of problems with the small model towing system in the Deep Water Basin, the results are not included in the main body of this report, but are presented in Appendix A.

The small model experiments were performed using the techniques used by DL/SIT with the small CVV-B model. This included the method used for turbulence stimulation, i.e., stud size, location and spacing and the stud drag correction method.

The results of the resistance experiments and comparisons of the trends in resistance between the large and small models are presented in this report. The resistance performance of the small CVV-B model from the experiments performed at DTNSRDC are compared with the results from DL/SIT. The full scale effective

power predictions based on the small model results are compared with the large model effective power predictions.

## EXPERIMENTS

### MODELS

The small models, 5385, 5386, and 5387, represent the three CVV design variants CVV-A, CVV-B, and CVV-D, respectively. These three models are constructed of wood to a scale ratio of 144, resulting in a model length of 1.82 m (5.97 ft). Models 5385 and 5387 were built at DTNSRDC; Model 5386 was built at DL/SIT. The models have no appendages except for the skeg.

The large models, 5368, 5372, and 5382, also represent the three CVV design variants CVV-A, CVV-B, and CVV-D, respectively. These three models are constructed of wood to a scale ratio of 31.435, resulting in a model length of 8.34 m (27.36 ft). All of the appendages, except for the skeg, were removed before the experiments.

The principal dimensions of the ships and models are given in Table 1. The CVV-A models were ballasted to represent a full scale displacement of 63430 t (62430 L. tons), and an even keel draft of 10.36 m (34.0 ft); the CVV-B models were ballasted to represent a full scale displacement of 63430 t (62430 L. tons) and an even keel draft of 10.36 m (34.0 ft); and the CVV-D models were ballasted to represent a full scale displacement of 62970 t (61980 L. tons) and an even keel draft of 10.55 m (34.6 ft).

The small models were towed using the planing boat towing bracket on loan from the USNA model basin. This bracket attaches to the model at one point, and fixes the model in sway, yaw, and roll. The drag measurements were taken with a 5 pound block gauge. Figure 1 shows a photograph of the tow bracket and block gauge fitted in a model.

In the 140 Foot Basin, the small models were connected to the carriage by a braced vertical strut. A number of experiments were performed to improve the strut bracing system and the number and location of rubber blocks to dampen vibration. The improvements were judged by the size of the noise reduction in the drag signal. The noise in the drag signal was reduced by a factor of three with the final bracing system from that obtained with the initial set-up.

#### TURBULENCE STIMULATION

Turbulence stimulation was required on the small models to obtain turbulent flow over the hull. Studs were selected for turbulence stimulation because DL/SIT has indicated that, when studs were used for turbulence stimulation, the resistance data were more consistent than when either struts or sand strips were used. Also, the DL/SIT resistance experiments with the small CVV-B model were performed using studs for turbulence stimulation. The stud size, spacing, and longitudinal location used with the small models were based on those used by DL/SIT with the CVV-B model. The studs, 3.2 mm (0.125 in.) dia by 2.5 mm (0.10 in.) high, were spaced 6.4 mm (0.25 in.) apart, and 15 mm (0.6 in.) aft of, and parallel to, the stem. The longitudinal location was selected using a method by Hughes<sup>1</sup>, which uses the entrance half angle to determine the stud longitudinal location.

The studs not only induce turbulence, but also add a drag component to the total measured resistance. This stud parasitic drag component must be subtracted out from the measured resistance to obtain the resistance of the hull alone. The method of stud parasitic drag correction used by DL/SIT in the analysis of the small CVV-B model assumes that, at higher speeds, the model without studs has turbulent flow over the entire hull (except in the immediate area of the stem)

so that turbulence stimulation is unnecessary. Therefore, the difference in resistance between the model with and without studs at the high speeds is the stud parasitic drag.

No turbulence stimulation was used with the large models because it is not considered necessary with large models; also, none was used in previous experiments with the large models.

#### EXPERIMENTAL PROCEDURE

The large and small CVV models were evaluated over a speed range corresponding to 5.1 m/s to 15.4 m/s (10 knots to 30 knots), full scale, or  $F_n = 0.10$  to 0.30. The resistance values were measured using a block gauge. The large model resistance data was sampled over a period of 5 seconds. The small model resistance data from the 140 Foot Basin was sampled over a period ranging from 7 to 24 seconds; the longer sampling periods correspond to lower model speeds.

#### PRESENTATION OF RESULTS

The measured and faired resistance values for the large and small CVV models are shown in Figures 2 to 12, and the measured resistance values are shown in Tables 2 to 12. The resistance values for the small CVV-B model from the experiments at DL/SIT are also included. The resistance curves are faired indirectly by fairing the residuary resistance coefficient ( $C_R$ ) values, shown in Figures 13 to 19. The  $C_R$  values are calculated from the total resistance,  $R_{TM}$ , using the ITTC correlation line.

At the low Froude numbers, there is noticeable scatter in the small model  $C_R$  values, especially when the models are not fitted with studs. Because the models without studs do not have turbulence stimulation, the location of the transition point at which the flow over the hull changes from laminar to

turbulent may vary even though the speed is held constant. Since the frictional resistance with laminar flow is significantly lower than that for turbulent flow, a change in the location of the flow transition may result in a noticeable change in the total resistance. The negative  $C_R$  values for the unstimulated models are a result of the  $C_R$  values calculated using the ITTC model-ship correlation line, which assumes that the flow over the hull is turbulent; however, because of the amount of laminar flow which existed over part of the hull, the actual frictional resistance was lower than that given by the ITTC model-ship correlation line. Thus, the negative values of  $C_R$  appearing in Figures 13 through 19 have no physical significance. It should be noted that, because the resistance data for the models without studs are used only to determine the stud drag correction, which uses only the resistance data at higher speeds, the  $C_R$  scatter and negative  $C_R$  values at the lower speeds for the models without studs do not effect the model resistance results. The  $C_R$  scatter and negative  $C_R$  values for the models with studs may be due to insufficient turbulence stimulation at very low speeds. Another reason for the scatter is that the resistance values measured are extremely small, and might not be resolved with sufficient accuracy at the lower speeds.

To assist in the low speed  $C_R$  fairing, a method presented by Prohaska<sup>2</sup> is used. The data, replotted as  $C_{TM}/C_{FM}$  versus  $F_n^4/C_{FM}$ , are shown in Figures 20 to 26. Prohaska states that over the range of  $F_n = 0.1$  to  $F_n = 0.2$ , a curve fitted to these points is a relatively straight line for most models. Because of the way the low speed data are compressed, it is much simpler to fair the Prohaska plots than to fair the  $C_R$  plots; therefore, the results from faired Prohaska curves are used to assist in fairing the  $C_R$  curves. The  $C_{FM}$  values are from the ITTC model-ship correlation line.

An additional benefit of using the Prohaska plots is that the form factor  $(1+k)$  value used in the Hughes<sup>3</sup> method of model-ship extrapolation is easily obtained. The  $C_{TM}/C_{FM}$  value at the intersection of the faired curve with  $F_n^4/C_{FM}$  = 0.0 is equal to the form factor,  $1+k$ .

Curves of total resistance coefficient ( $C_{TM}$ ) versus Froude number for the small models are shown in Figures 27 to 30. The curves of the difference between the  $C_{TM}$  curves of the small models with and without studs,  $\Delta C_{TM}$ , are also presented in these graphs.

The stud drag coefficient,  $C_{SD}$ , is considered to be constant with speed, and is calculated by averaging the  $\Delta C_{TM}$  curves at the high Froude number range, where the difference in resistance between the models fitted with and without studs are considered to be only due to the drag of the studs. DL/SIT averaged the  $\Delta C_{TM}$  curve above  $F_n = 0.2$  for the small CVV-B model; however, since the  $\Delta C_{TM}$  values are not relatively constant until the higher Froude numbers are reached, in the present work the  $\Delta C_{TM}$  curves are averaged above Froude number  $F_n = 0.28$ , depending upon the shape of the  $\Delta C_{TM}$  curve.

Figure 31 shows the ratio of  $R_{TM}$  (DL/SIT) to  $R_{TM}$  (140 Foot Basin) versus Froude number for the small CVV-B model fitted with studs.

To show the relative resistance performance of the models, the full scale predicted resistance curves were normalized by the average of the full scale predicted resistance of the models. The average resistance,  $R_{TS}(\text{AVE})$  is defined as:

$$R_{TS}(\text{AVE}) = (R_{TS}(\text{CVV-A}) + R_{TS}(\text{CVV-B}) + R_{TS}(\text{CVV-D}))/3.$$

The large model full scale resistance curves were normalized by the average full scale resistance for the large models, and the small model full scale resistance

curves were normalized by the average full scale resistance for the small models. These curves of  $R_{TS}/R_{TS}$  (AVE) are shown in Figures 32 and 33 for correlation allowance  $C_A = 0.0005$  and  $0.00035$  for the small models, and  $0.00035$  for the large models. Changing the small model  $C_A$  value from  $0.00035$  to  $0.0005$  changed the relative resistance performances very little; the maximum change was  $1/2$  percent. Since changing the  $C_A$  value has a small effect on the relative resistance performances, and a small model  $C_A$  value of  $0.0005$  gave the best correlation between the large and small model full scale resistance predictions, a small model  $C_A$  value of  $0.0005$  will be used unless otherwise noted.

The  $R_{TS}/R_{TS}$  (AVE) curves for the CVV hull forms based on the Taylor Standard Series data are presented in Figure 34.

The predicted relative resistance performances of CVV-A, CVV-B, and CVV-D are shown in Figures 35 to 37, respectively. The large model, small model, and Taylor Standard Series  $R_{TS}/R_{TS}$  (AVE) predictions are plotted together.

Figures 38 to 40 show relative comparisons of the small model full scale predictions to the large model full scale predictions, presented as  $R_{TS}$  (small model)/ $R_{TS}$  (large model), versus Froude number. The model scale data are extrapolated using the ITTC model-ship correlation line with a large model  $C_A$  value of  $3.5 \times 10^{-4}$ . The small model data are extrapolated using both the Froude and Hughes method of extrapolation. The Hughes method assumes that

$$C_{TS} = C_R + (1+k)C_{FS} + C_A,$$

$$\text{where } C_R = C_{TM} - (1+k)C_{FM}.$$

A series of experiments were performed to obtain some measure of repeatability in the small model resistance data. The small models were tested at three

different speeds, repeating the speeds six times in a random pattern. The speeds corresponded to  $F_n = 0.18, 0.24$ , and  $0.28$ . The results are shown in Table 13, and are given in terms of maximum difference in the resistance values over the mean resistance value.

#### DISCUSSION OF RESULTS

Since the small CVV-B model was evaluated experimentally at both DTNSRDC and DL/SIT, the resistance results can be compared directly to determine if the experimental techniques and equipment used with the small models gave reasonable results. The faired curve of the DL/SIT resistance data, normalized by the faired  $R_{TM}$  data from DTNSRDC is shown in Figure 31. The maximum difference between the DTNSRDC and the DL/SIT resistance values is 1 percent; therefore, the DL/SIT results have been repeated very well.

The relative resistance  $R_{TS}/R_{TS}(\text{AVE})$  values for the large and small CVV-A models show excellent correlation: less than 1 1/2 percent difference between the relative resistance values above a Froude number of 0.16. The relative resistance values for the large and small CVV-B models have less than 1 percent difference below a Froude number of 0.24 and above a Froude number of 0.28; between  $F_n = 0.24$  and  $0.28$  the difference increases to 3 percent. The relative resistance values for the large and small CVV-D models have less than 2 percent difference. Therefore, the relative resistance performances of the small CVV models compare well to the relative resistance performances of the large CVV models.

The relative resistances of the CVV hull forms were also predicted using a Taylor Standard Series approximation. The  $R_{TS}/R_{TS}(\text{AVE})$  curves based on the Taylor Standard Series predictions have no similarity with the large model relative resistance curves except at the highest speeds. Therefore, for these CVV hull

forms, the small models were far more effective in predicting the change in resistance due to changes in the hull form than the Taylor Standard Series. It should be noted that the accuracy of the Taylor standard series predictions may improve with significantly different hull form shapes.

The small model resistance data are extrapolated to full scale and can be compared with the large model predictions as seen in Figures 38 to 40. The small model Froude method resistance predictions with the same  $C_A$  value as the large models, ( $C_A = 3.5 \times 10^{-4}$ ) are lower than the large model predictions by as much as 9 percent. If the  $C_A$  value used with the small model predictions is increased to  $5.0 \times 10^{-4}$  to minimize the average difference, then the differences between the large and small model predictions are within  $\pm 4$  percent. The higher  $C_A$  value for the small models seems reasonable; small models have greater scale effects than large models. The small model Hughes method resistance predictions need an even larger  $C_A$  value,  $6.0 \times 10^{-4}$ , to minimize the difference between the large and small model predictions. The small model resistance predictions are higher than the large model predictions at lower speeds, and lower at the high speeds.

It should be noted that the small model  $C_A$  value was increased based on the comparison of the large and small model predictions. With a significantly different hull form, the small model  $C_A$  value could be quite different relative to the large model  $C_A$  value. The  $C_A$  values used with the large models were developed through comparisons of model predictions to ship trial data, accumulated over a long period of time. Similar efforts would be required for accurate determination of the appropriate  $C_A$  values to be used in small model resistance extrapolation. Also, even with an "adjusted"  $C_A$  value for the small models, the small model predictions differed from the large model predictions by  $\pm 4$  percent. It appears that the method in use at DTNSRDC to predict full scale resistance from large

model data is not appropriate to use with the small CVV model data for the prediction of full scale resistance. Because of the small sample (only three small models were tested), no general conclusions may be drawn with respect to the use of small models for resistance prediction.

The results from the small model repeatability experiments in Table 13 show that the maximum difference in the resistance values was 3.5 percent. A similar experiment, performed at DL/SIT with a 1.86 m (6.1 foot) SCS model (Model 5384) showed a maximum difference in the resistance values of 4 percent. Based on this comparison, the repeatability obtained at DTNSRDC seems reasonable.

#### CONCLUSIONS

1. The relative resistance performance of the small CVV models compare well with that of the large CVV models, and, gives significantly better resolution than Taylor Standard Series for the CVV hull forms evaluated.
2. For the extrapolation of resistance data to full scale, the small CVV models needed a larger correlation allowance than the large models for comparable full scale predictions. The appropriate small model  $C_A$  value could not be selected without the availability of large model data. Even with the aid of large model data, the small CVV model predictions were only within  $\pm 4$  percent of the large model predictions. Thus, using the same method for full scale prediction, the small model data provides different results than the large model data for the CVV models reported here. Because of the small sample (three models) general conclusions can not be drawn.
3. The resistance results with the small CVV-B model repeated the DL/SIT results.
4. The repeatability of the small model data obtained at DTNSRDC was compatible with that obtained at DL/SIT.

#### RECOMMENDATIONS

1. The proper role of the use of small models in the ship design process should be explored.
2. The 140 Foot Basin should be updated for small model testing. The improvements should include the update of both mechanical and electrical/electronic equipment.

#### ACKNOWLEDGEMENTS

The author wishes to thank Mr. John Hoyt of the United States Naval Academy for his invaluable aid during this project.

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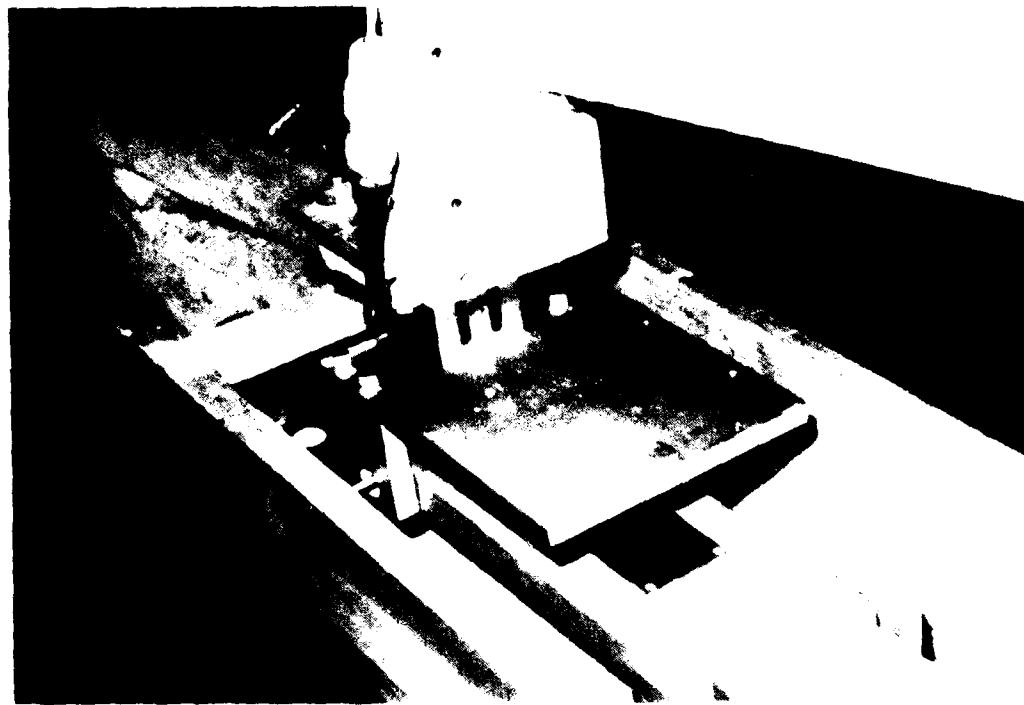
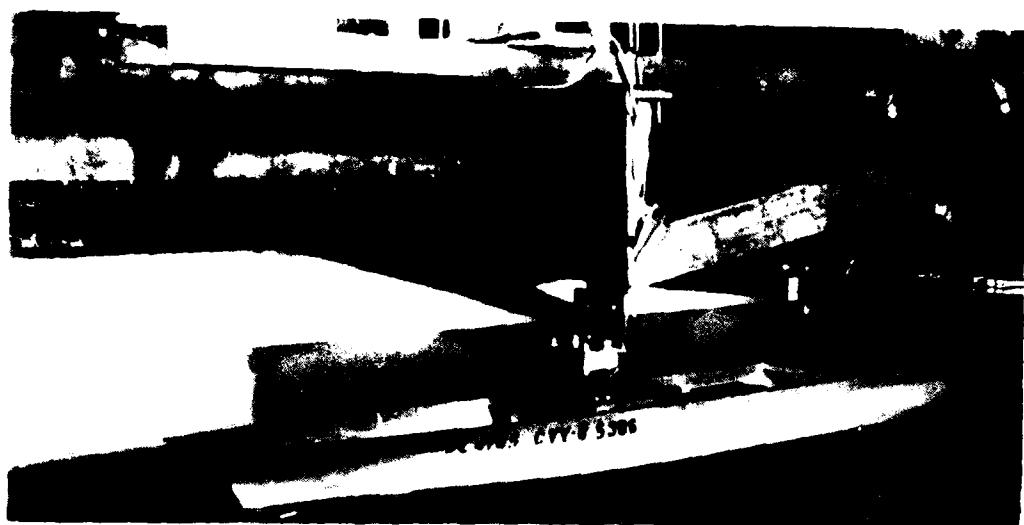


FIGURE 1 - SMALL MODEL TOWING ARRANGEMENT IN THE 140 FOOT BASIN

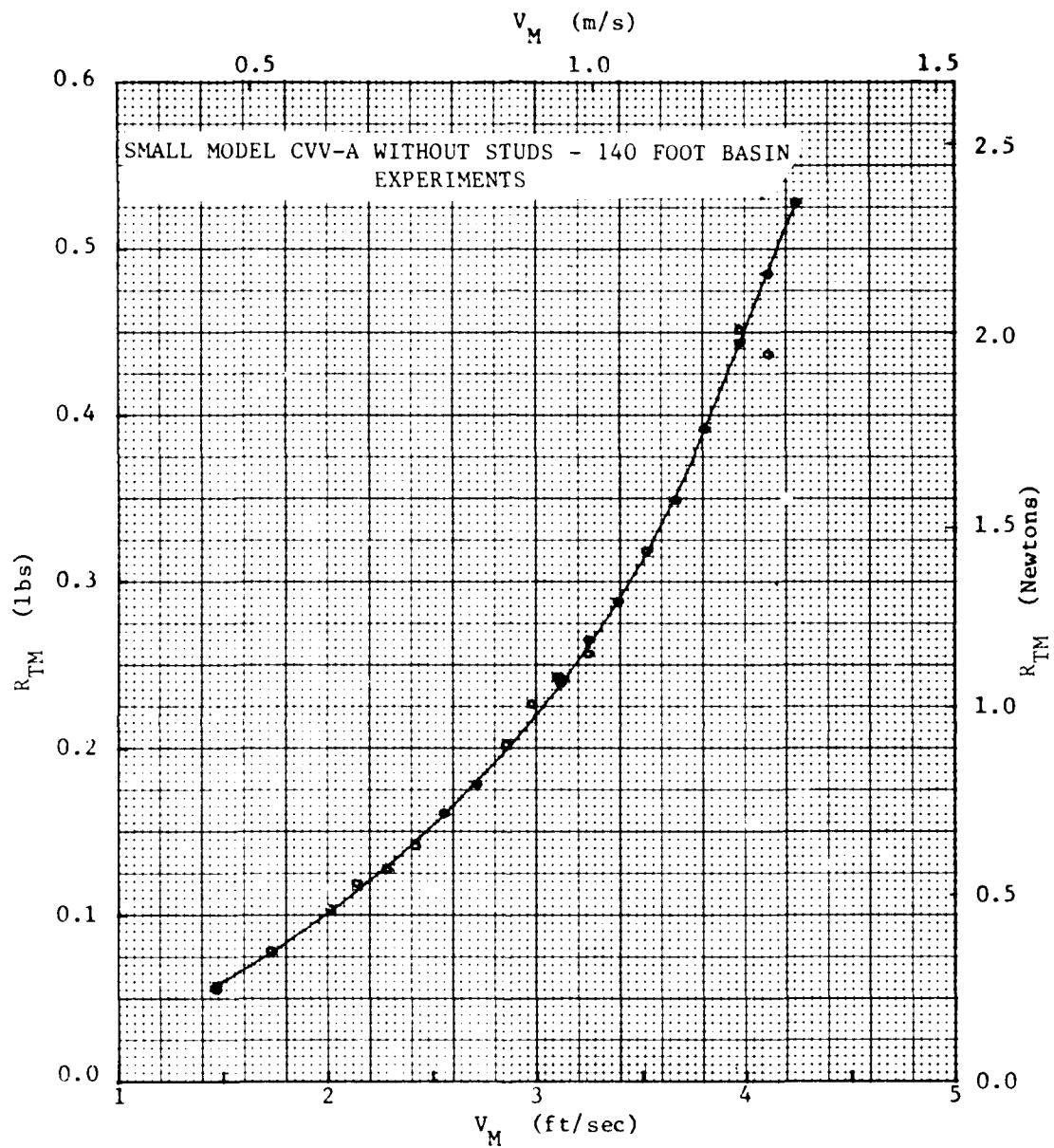


FIGURE 2 - RESISTANCE VALUES FOR THE SMALL CVV-A MODEL WITHOUT STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

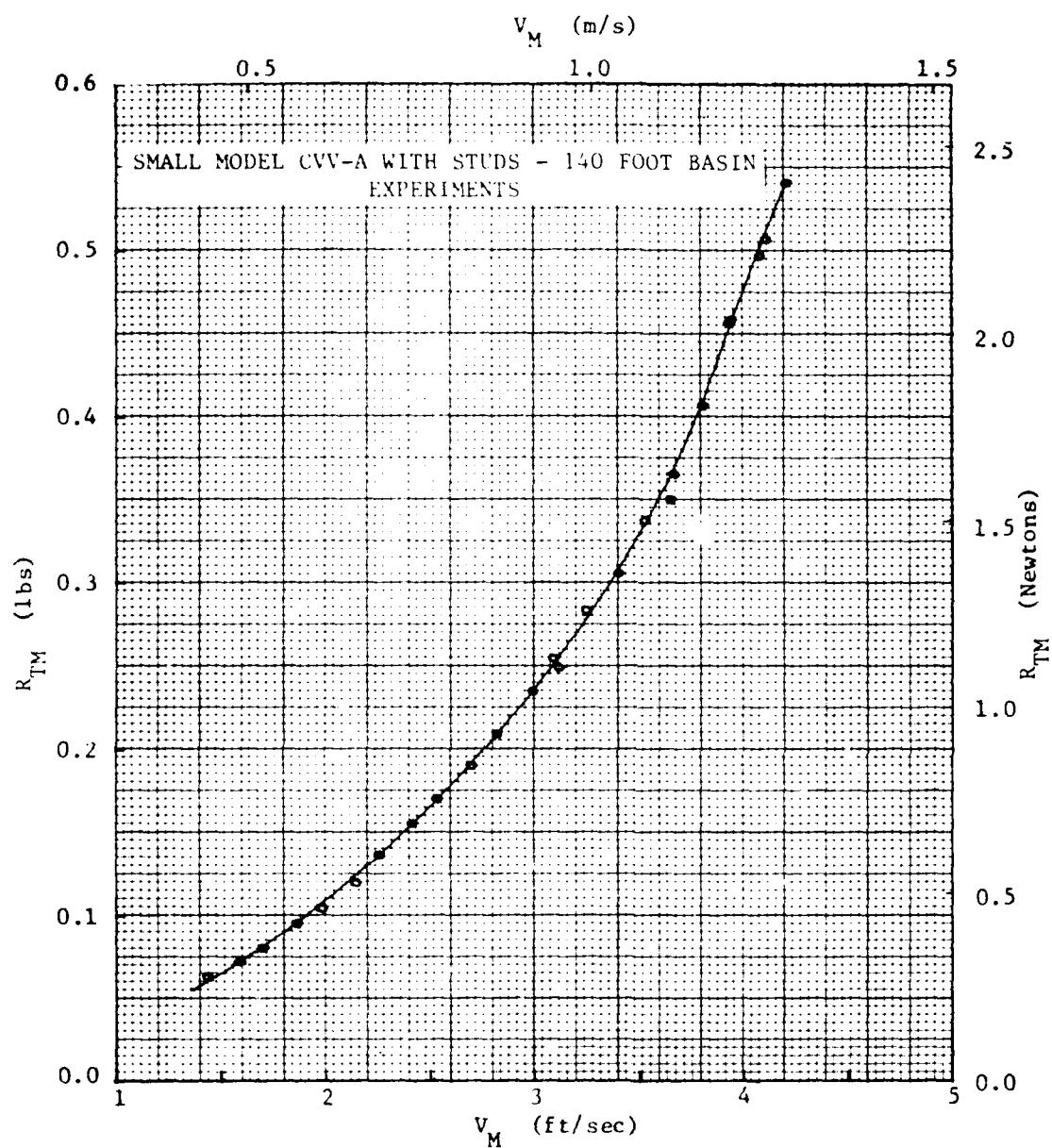


FIGURE 3 - RESISTANCE VALUES FOR THE SMALL CVV-A MODEL WITH STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

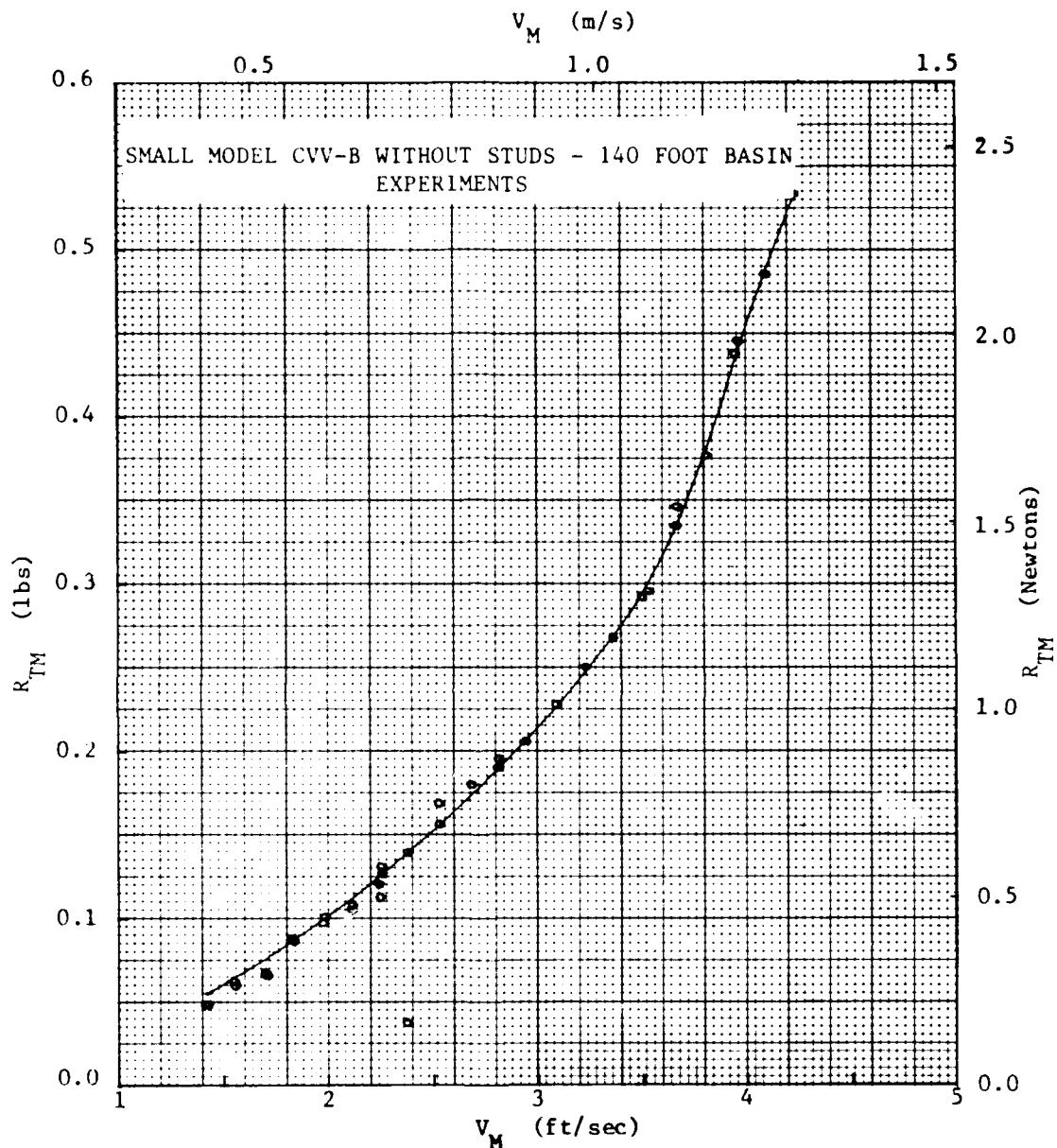


FIGURE 4 - RESISTANCE VALUES FOR THE SMALL CVV-B MODEL WITHOUT STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

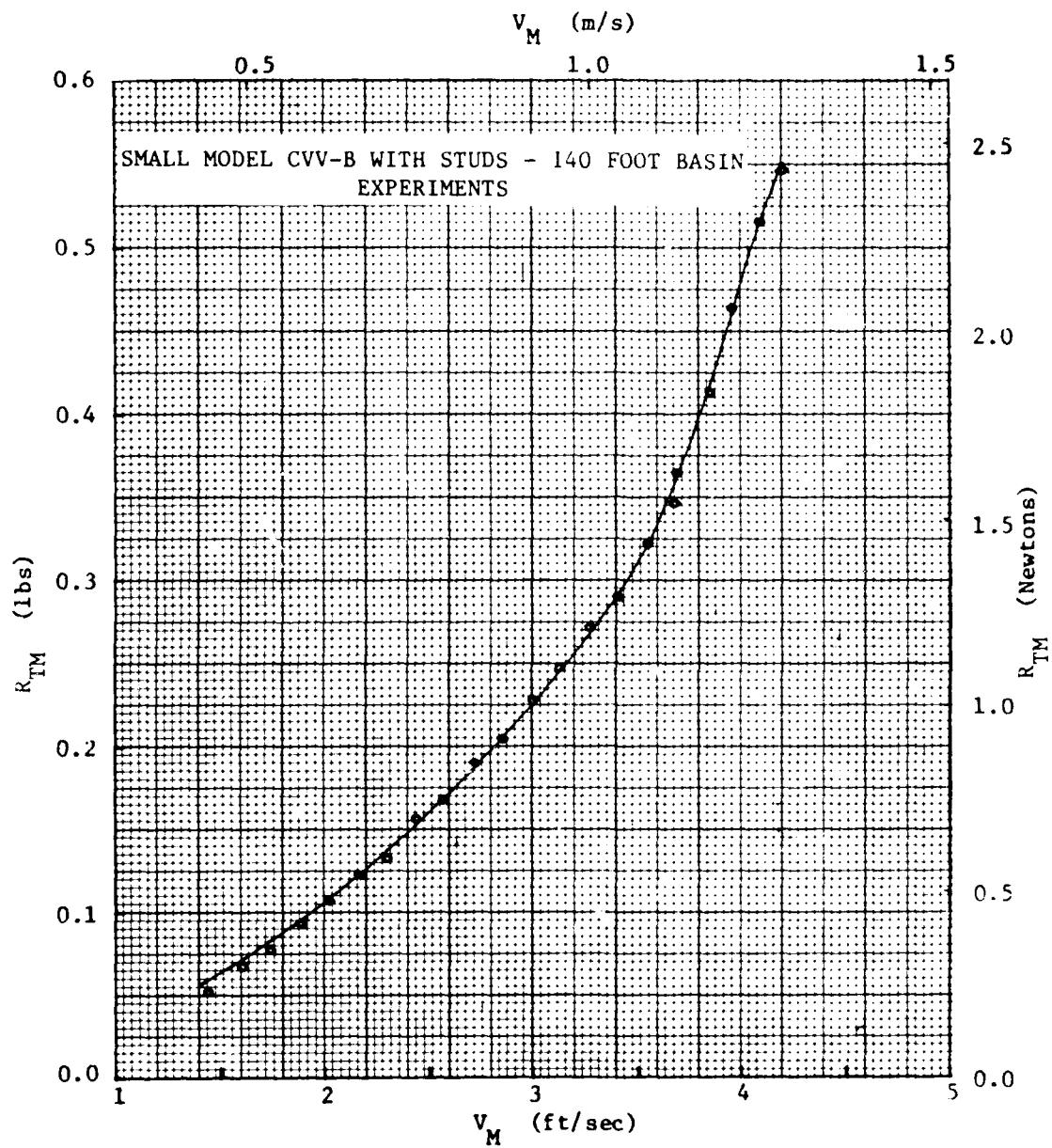


FIGURE 5 - RESISTANCE VALUES FOR THE SMALL CVV-B MODEL WITH STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

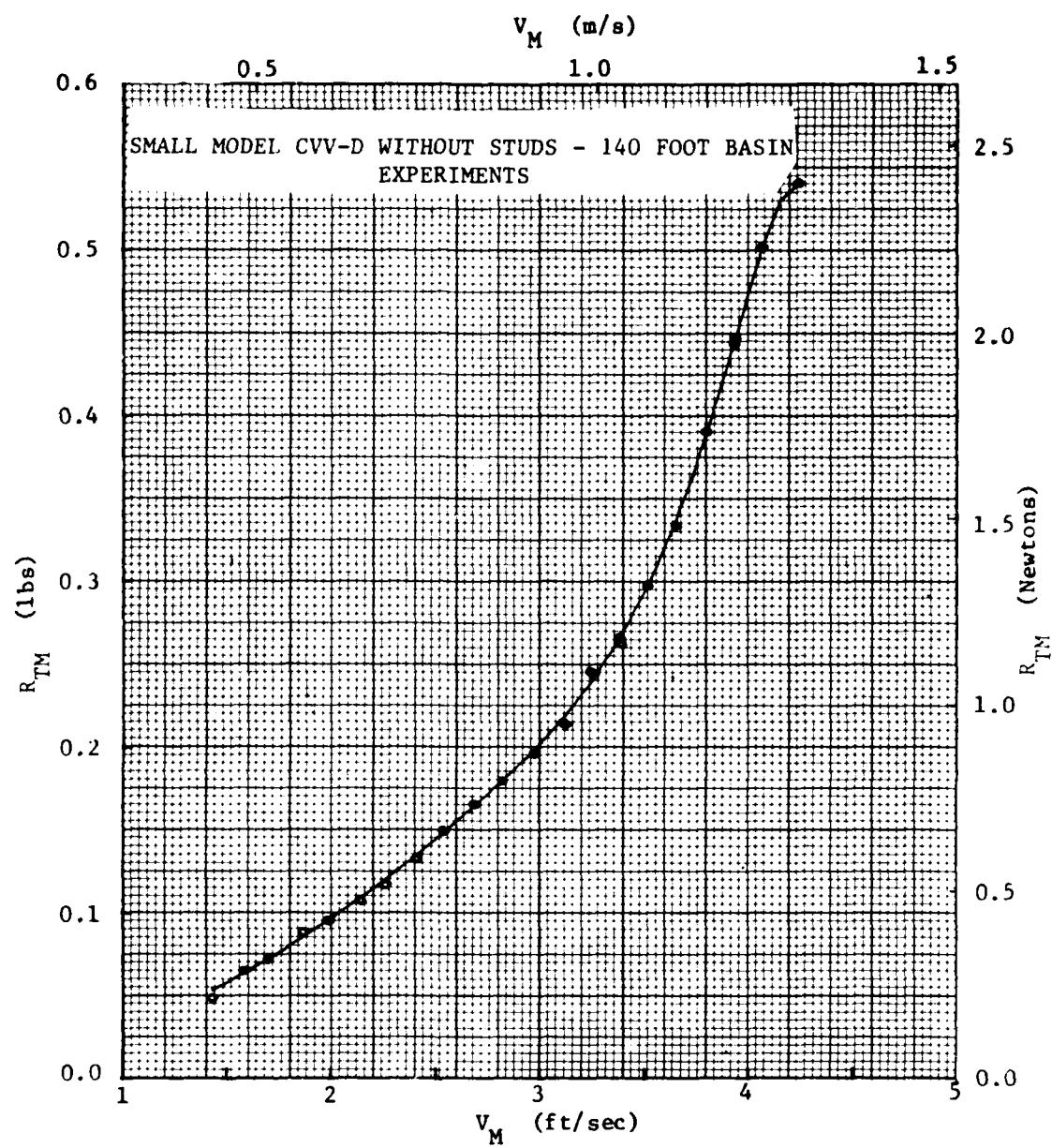


FIGURE 6 - RESISTANCE VALUES FOR THE SMALL CVV-D MODEL WITHOUT STUDS  
FROM THE 140 FOOT BASIN EXPERIMENTS

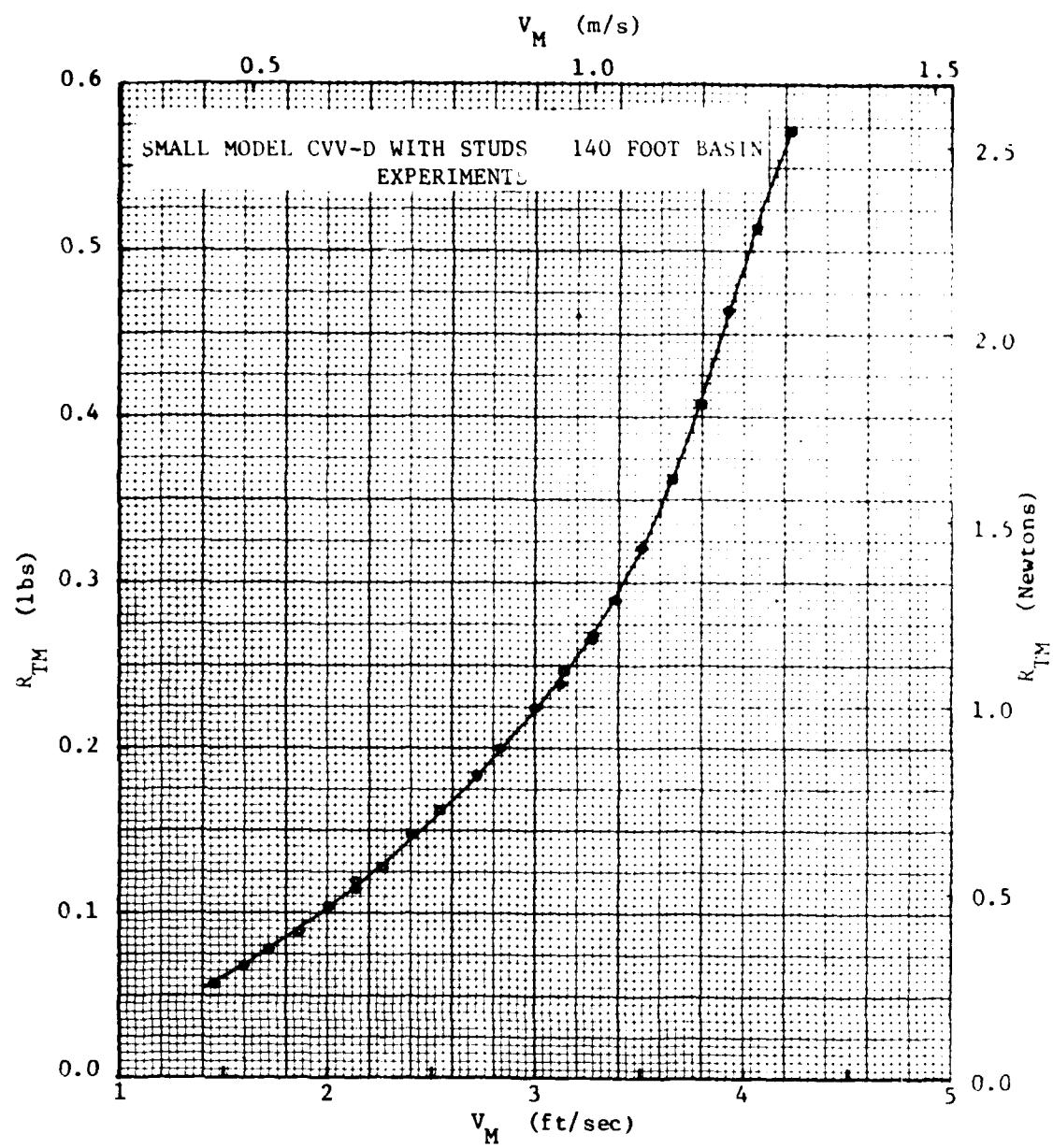


FIGURE 7 - RESISTANCE VALUES FOR THE SMALL CVV-D MODEL WITH STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

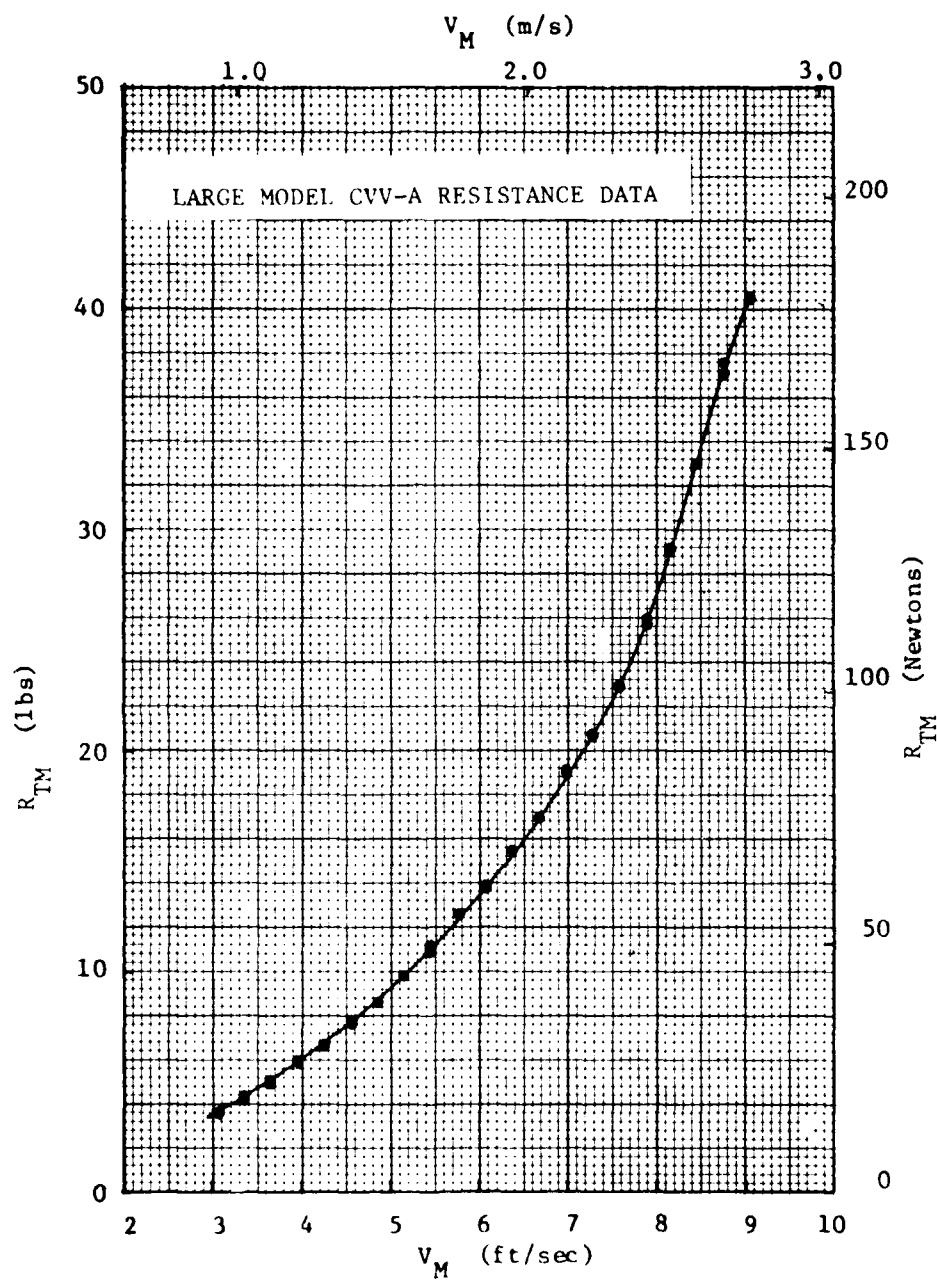


FIGURE 8 - RESISTANCE VALUES FOR THE LARGE CVV-A MODEL

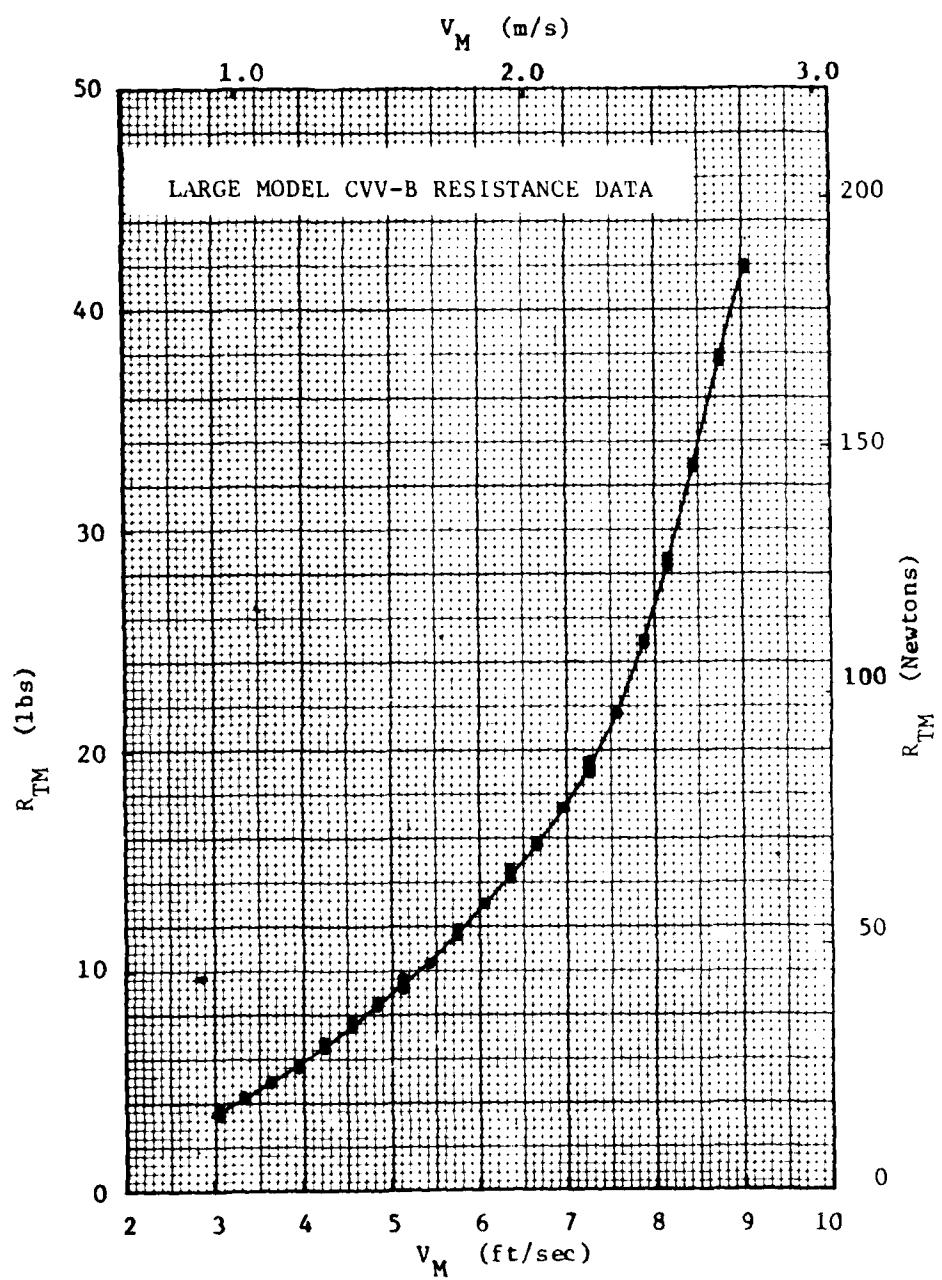


FIGURE 9 - RESISTANCE VALUES FOR THE LARGE CVV-B MODEL

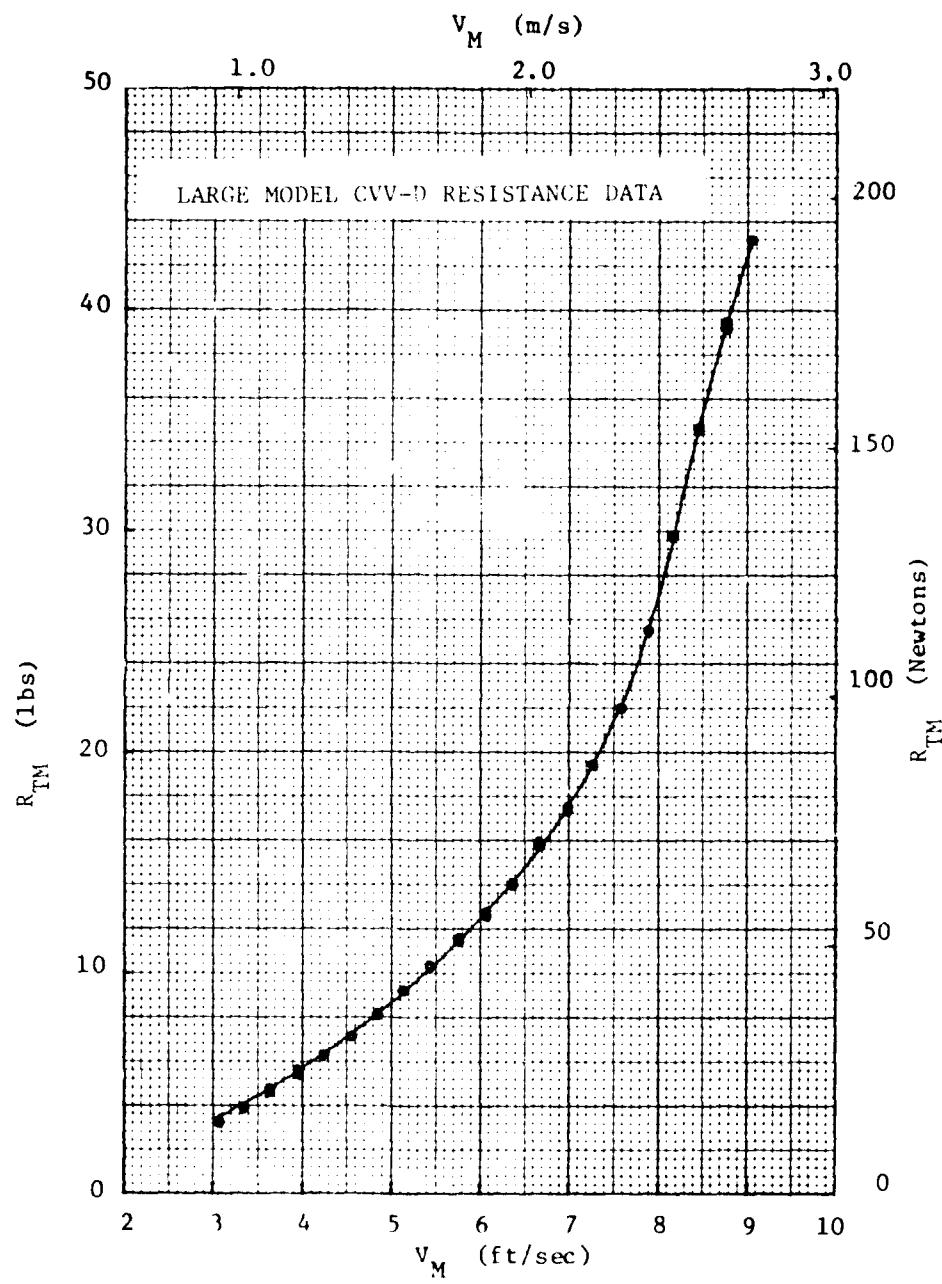


FIGURE 10 - RESISTANCE VALUES FOR THE LARGE CVV-D MODEL

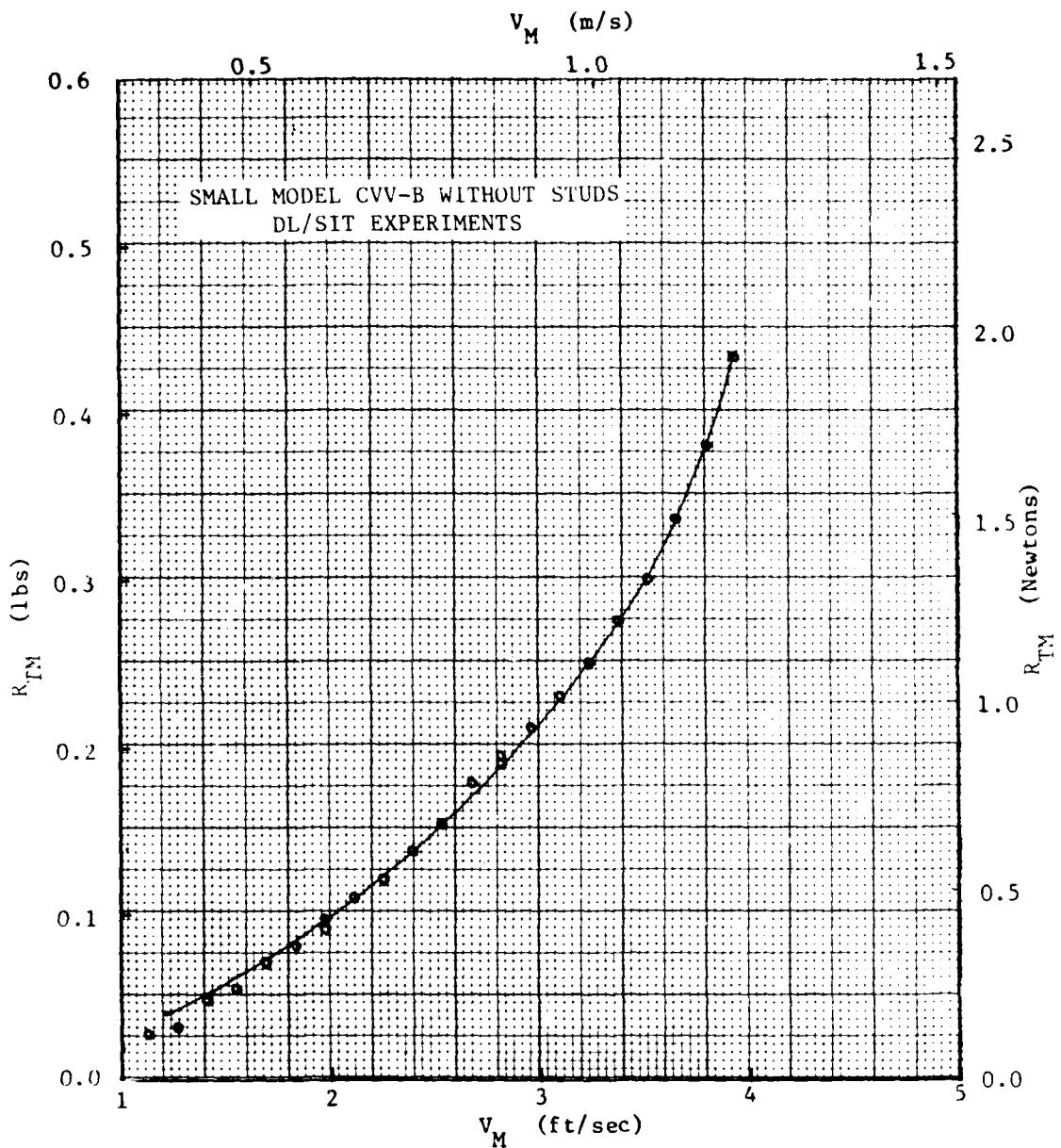


FIGURE 11 - RESISTANCE VALUES FOR THE SMALL CVV-B MODEL WITHOUT STUDS FROM DL/SIT

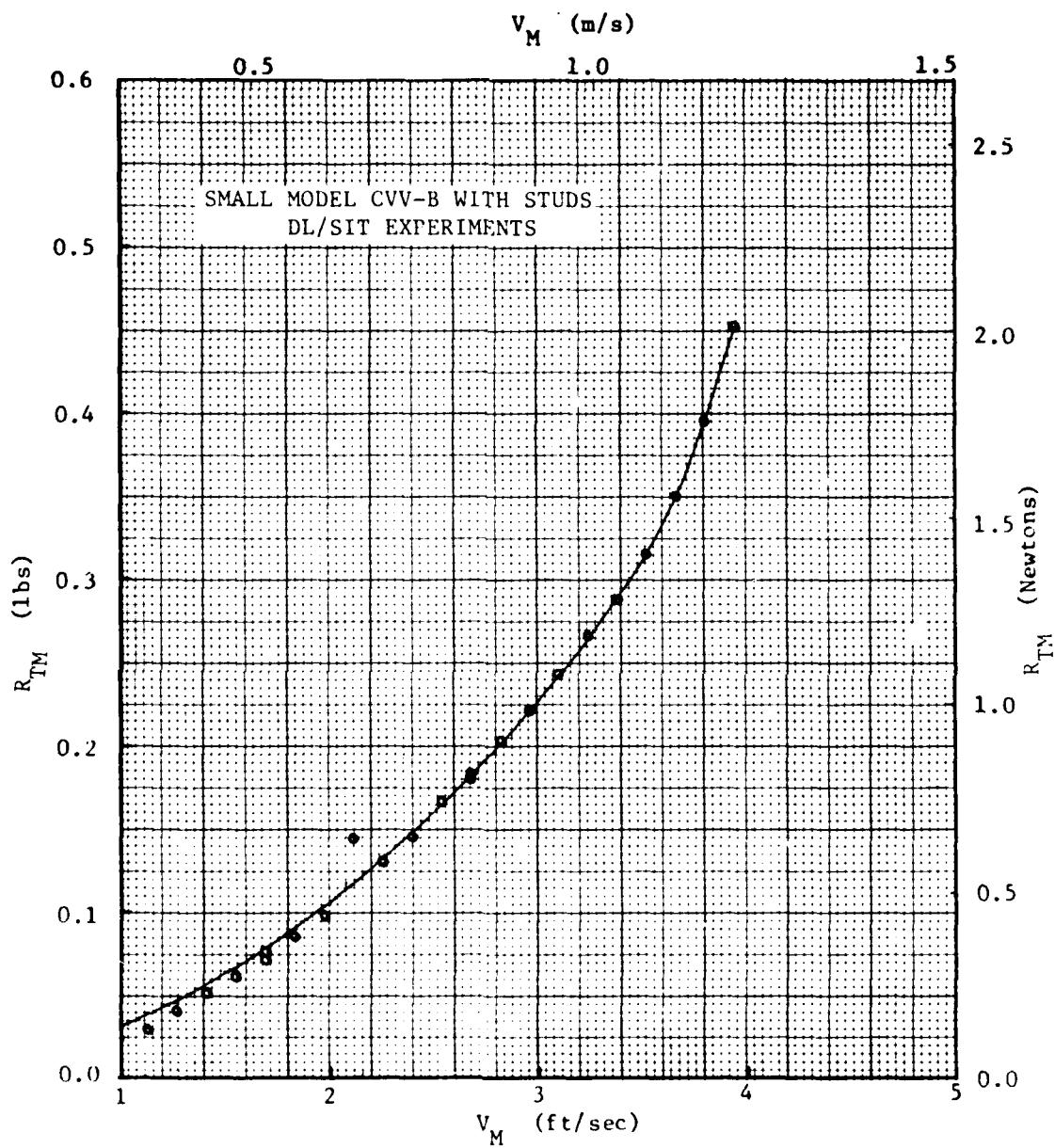


FIGURE 12 - RESISTANCE VALUES FOR THE SMALL CVV-B MODEL WITH STUDS  
FROM DL/SIT

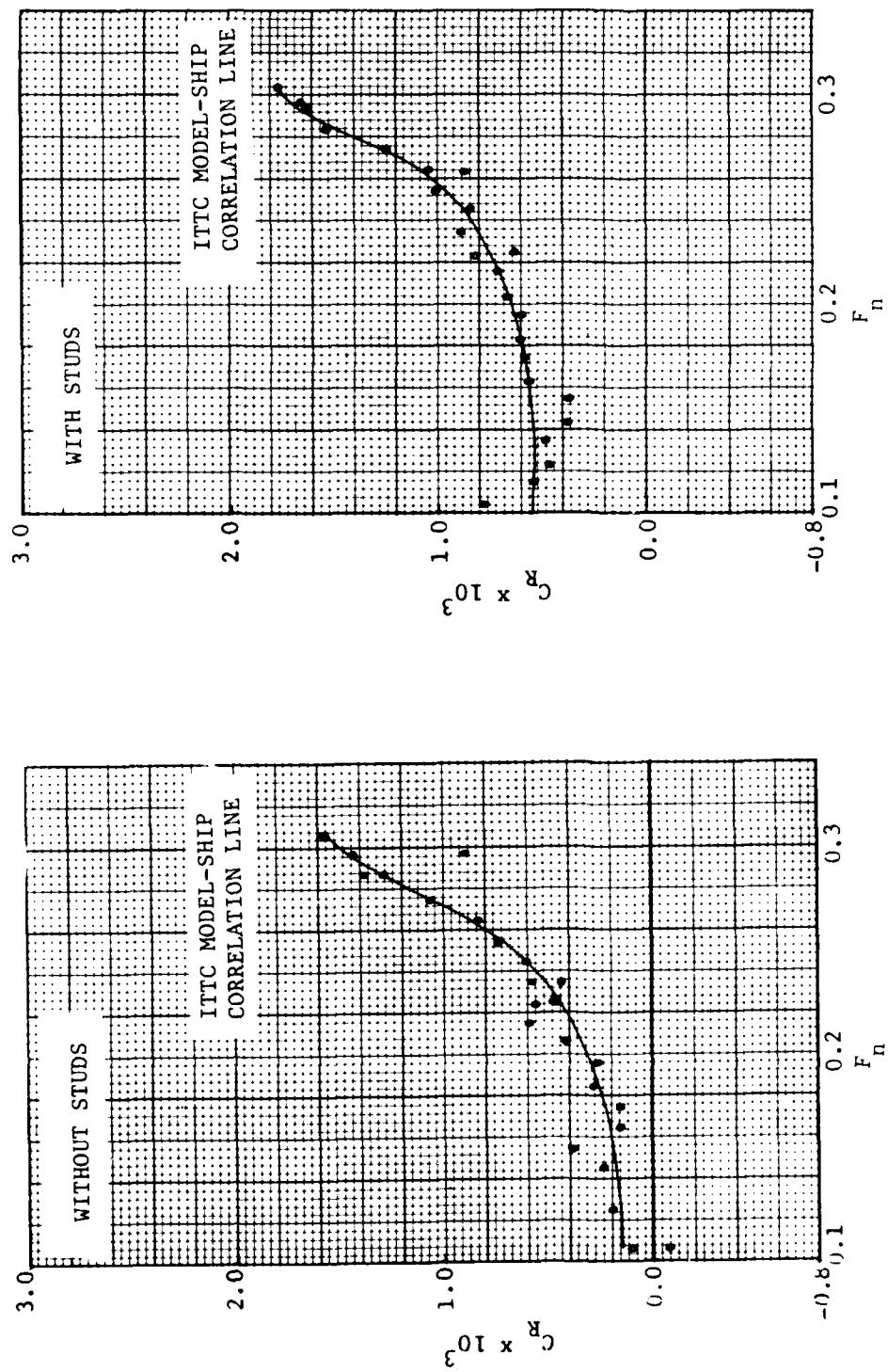


FIGURE 13 - RESIDUARY RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVN-A MODEL FROM THE 140 FOOT BASIN EXPERIMENTS

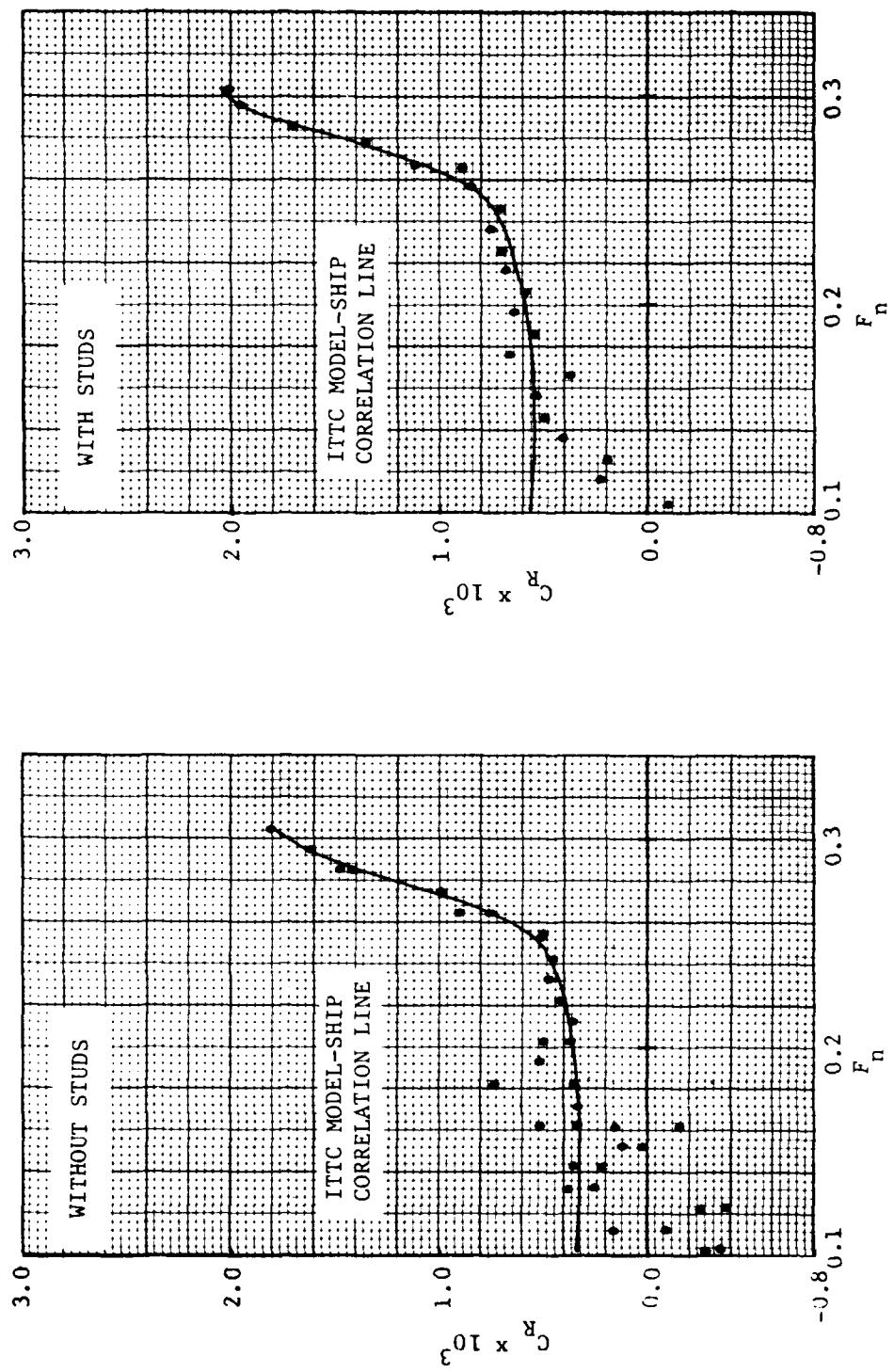


FIGURE 14 - RESIDUARY RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-B MODEL FROM THE 140 FOOT BASIN EXPERIMENTS

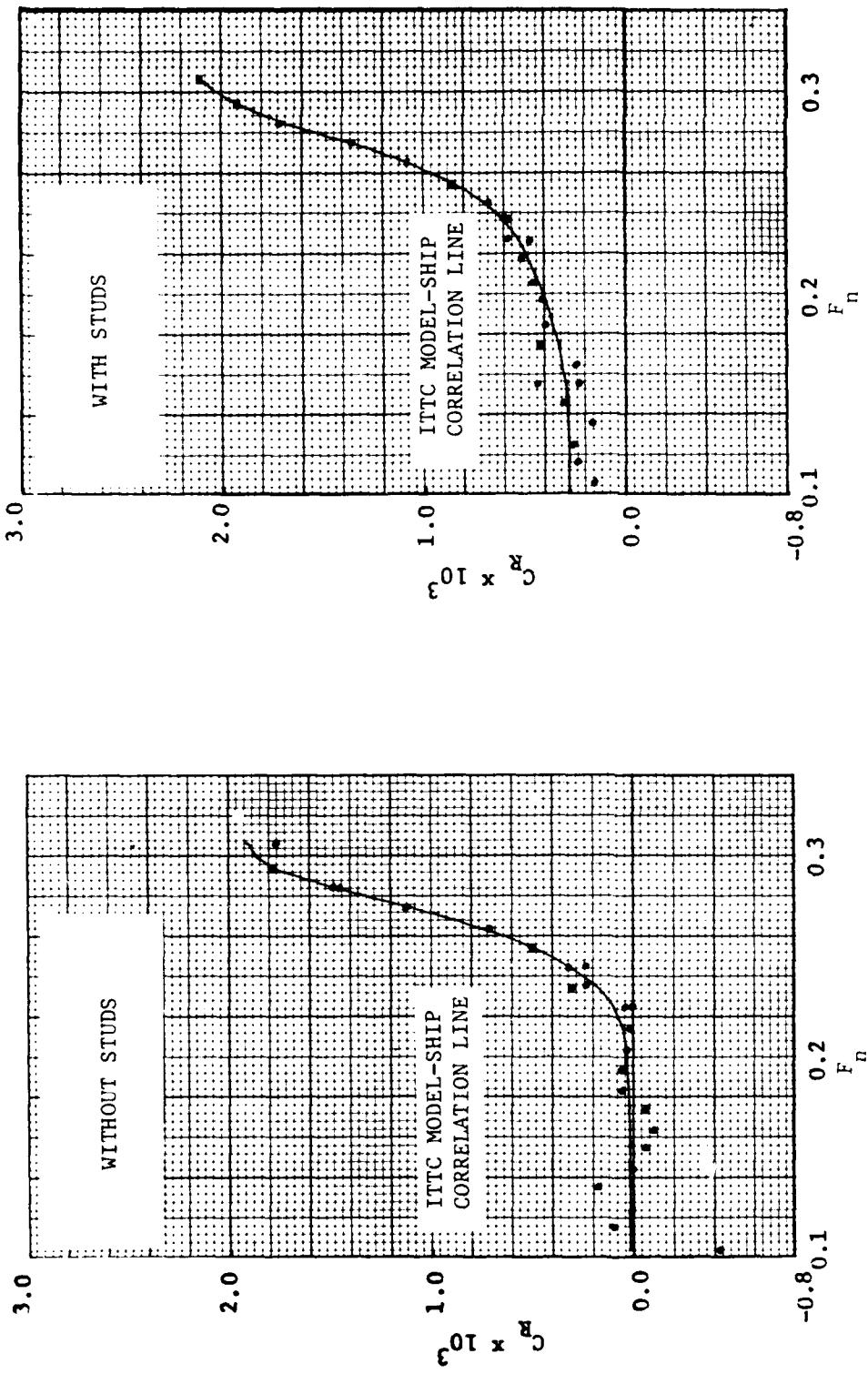


FIGURE 15 - RESIDUARY RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-D MODEL FROM THE 140 FOOT BASIN EXPERIMENTS

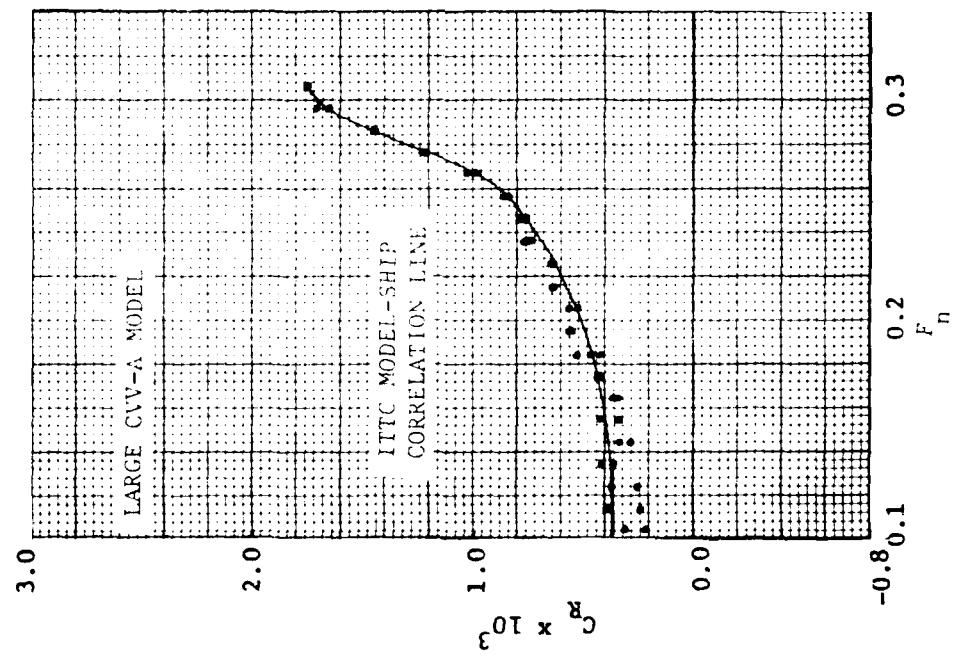


FIGURE 16 - RESIDUARY RESISTANCE COEFFICIENT CURVES  
FOR THE LARGE CVV-A MODEL.

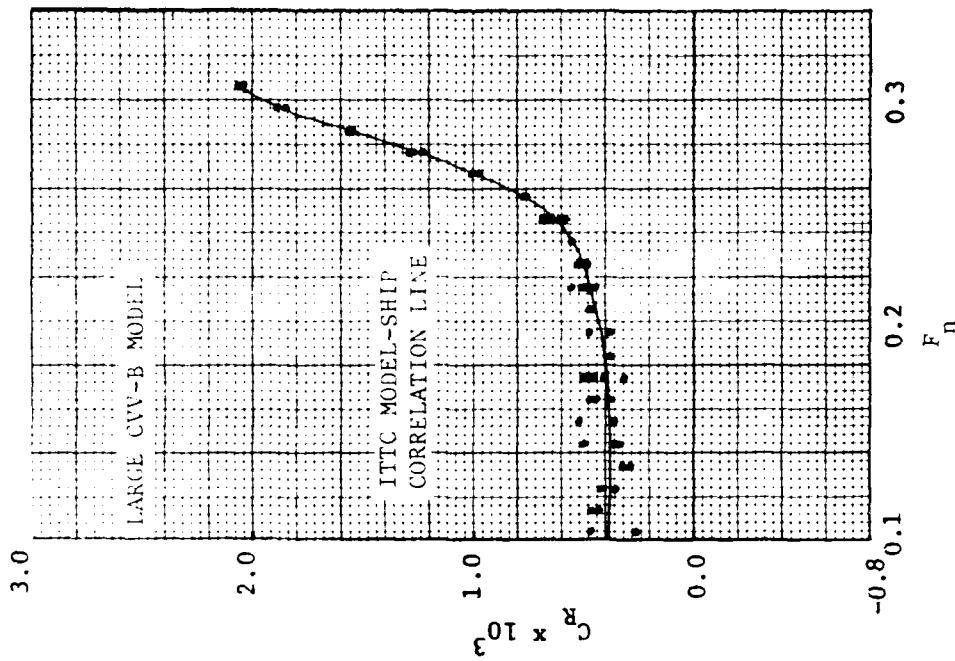


FIGURE 17 - RESIDUARY RESISTANCE COEFFICIENT CURVES  
FOR THE LARGE CVV-B MODEL.

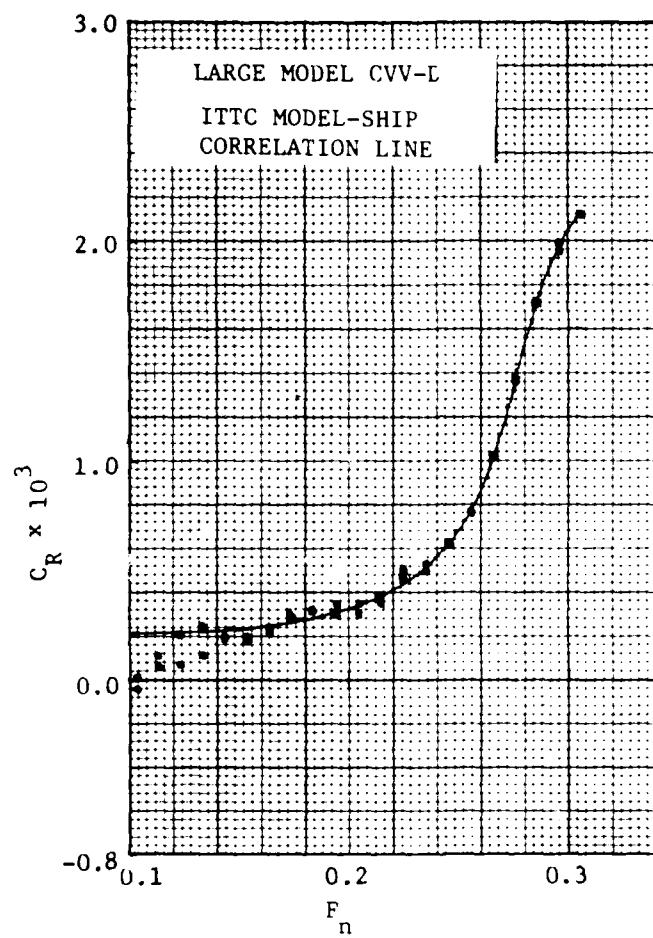


FIGURE 18 - RESIDUARY RESISTANCE COEFFICIENT CURVE FOR THE LARGE CVV-D MODEL

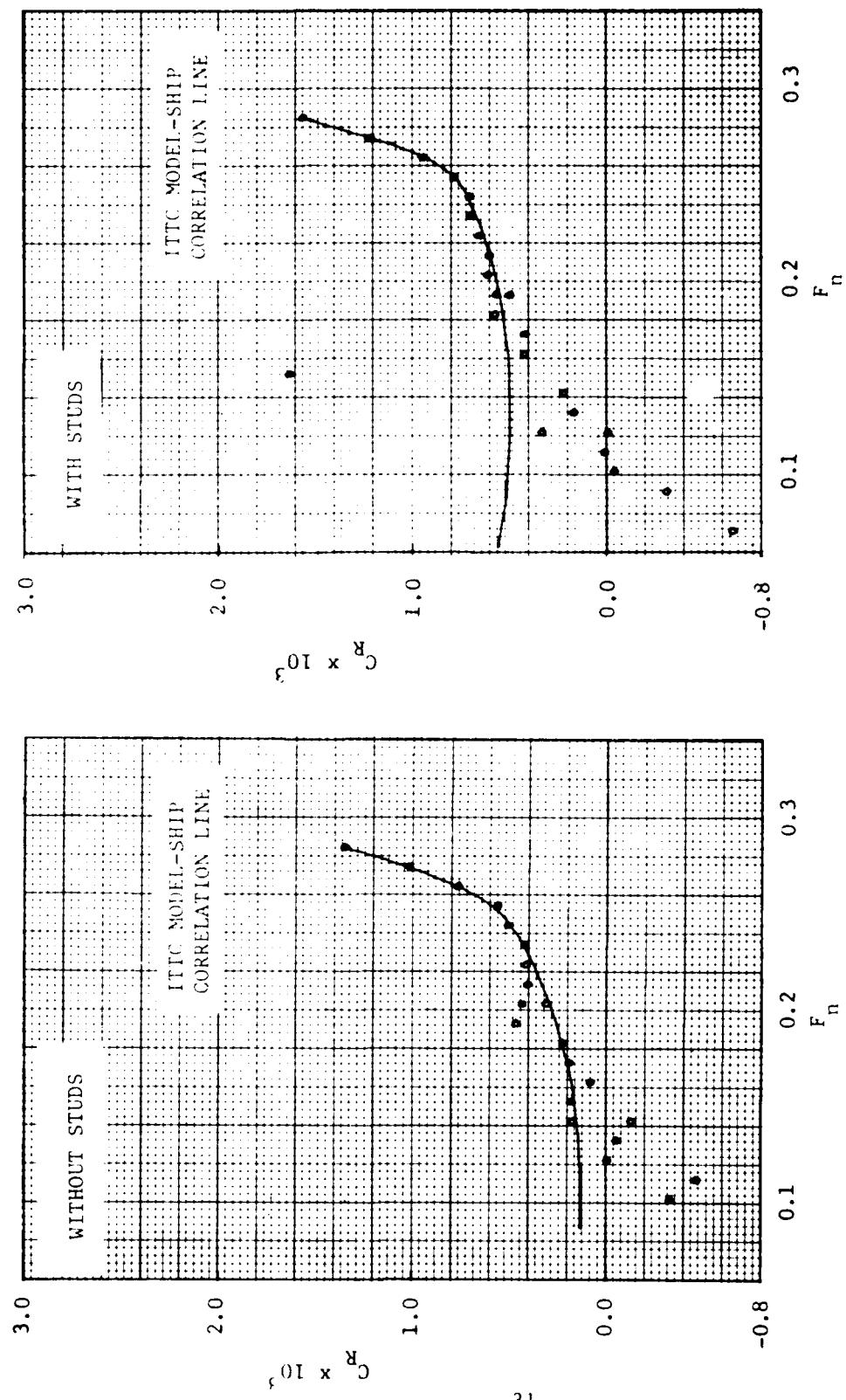


FIGURE 19 - RESIDUARY RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-B MODEL FROM DL/SIT

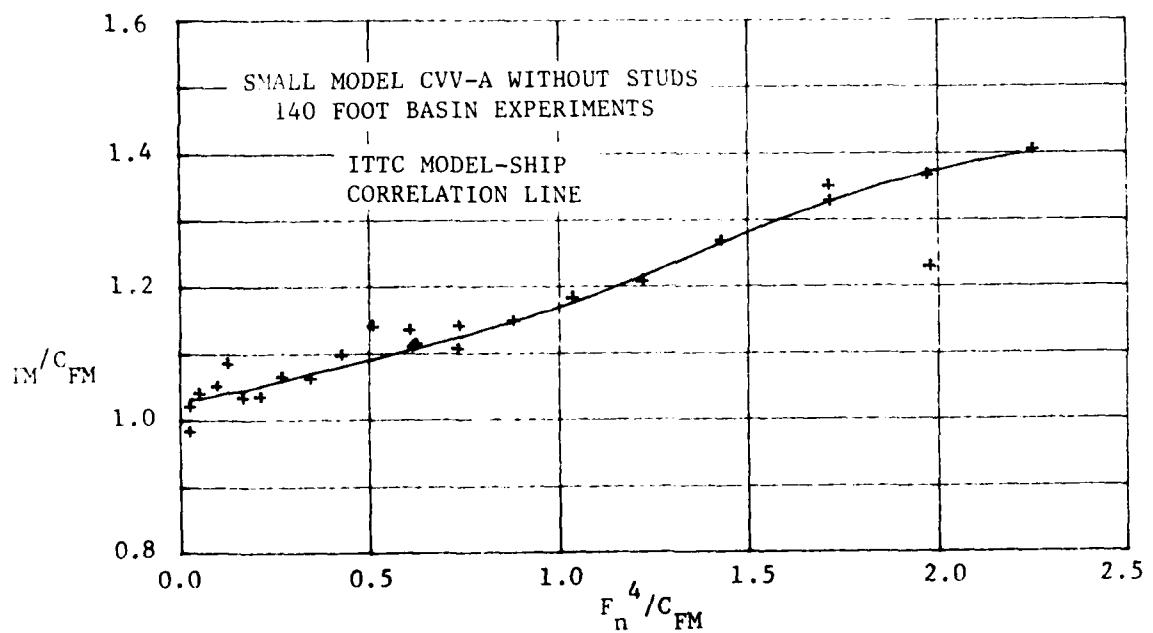
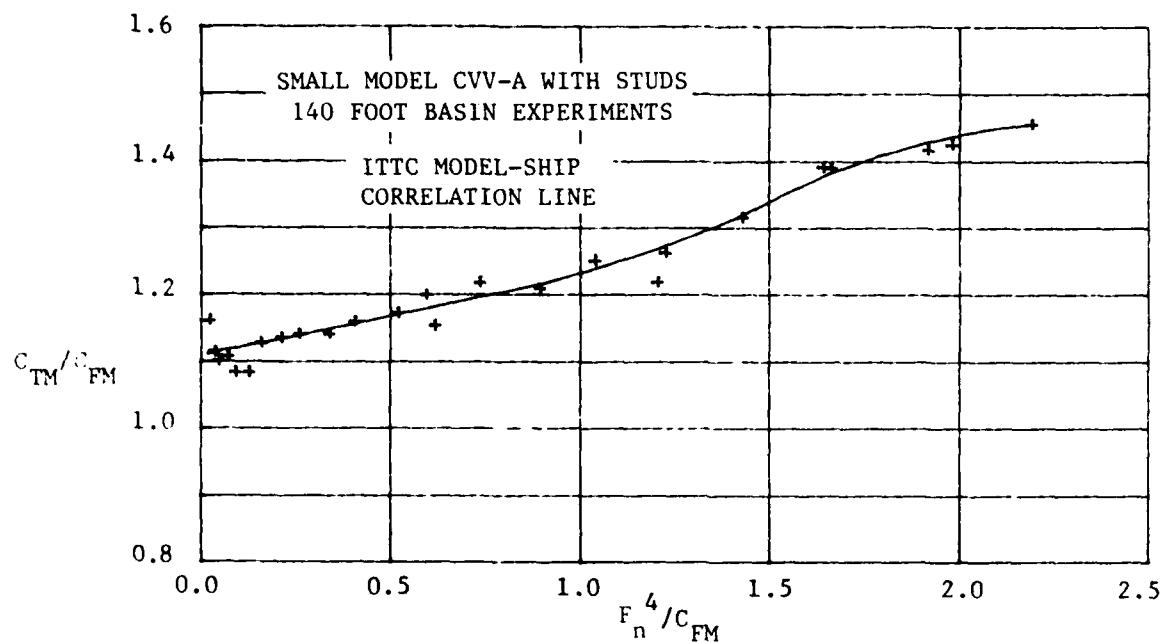


FIGURE 20 - PROHASKA PLOTS FOR THE SMALL CVV-A MODEL FROM  
THE 140 FOOT BASIN EXPERIMENTS

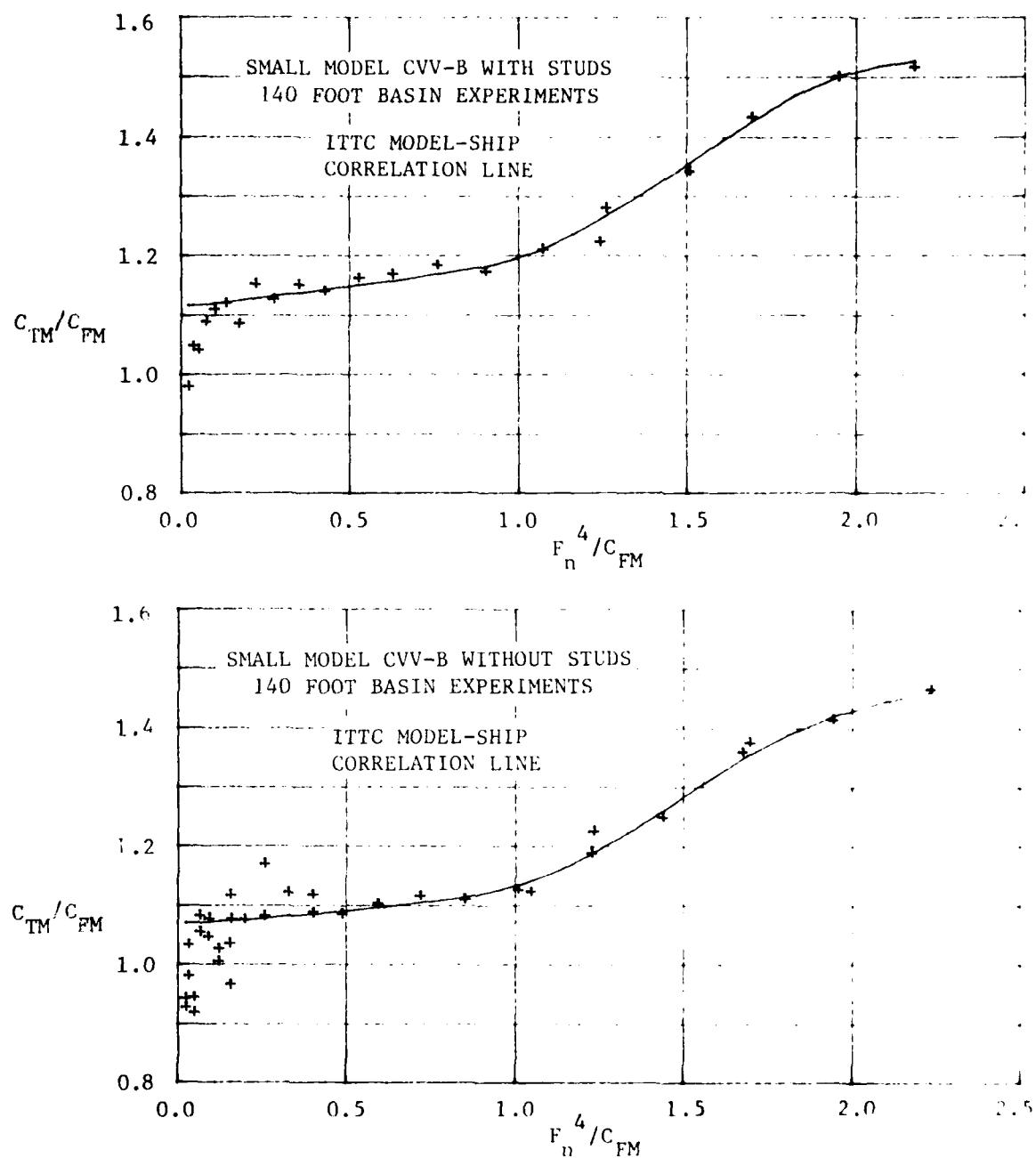


FIGURE 21 - PROHASKA PLOTS FOR THE SMALL CVV-B MODEL FROM THE 140 FOOT BASIN EXPERIMENTS

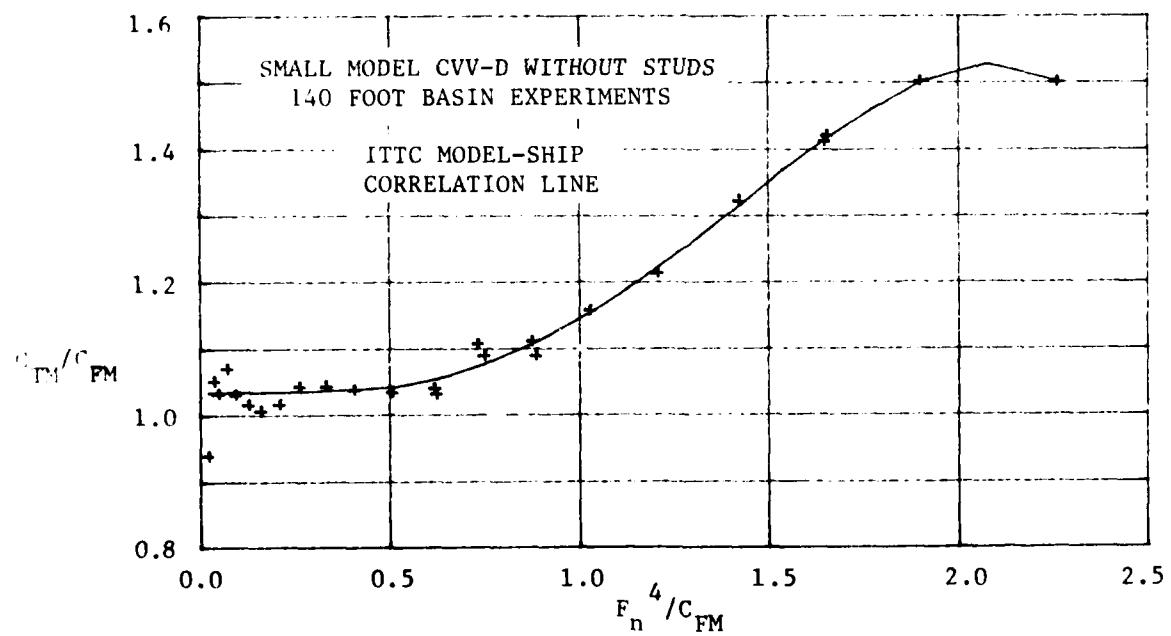
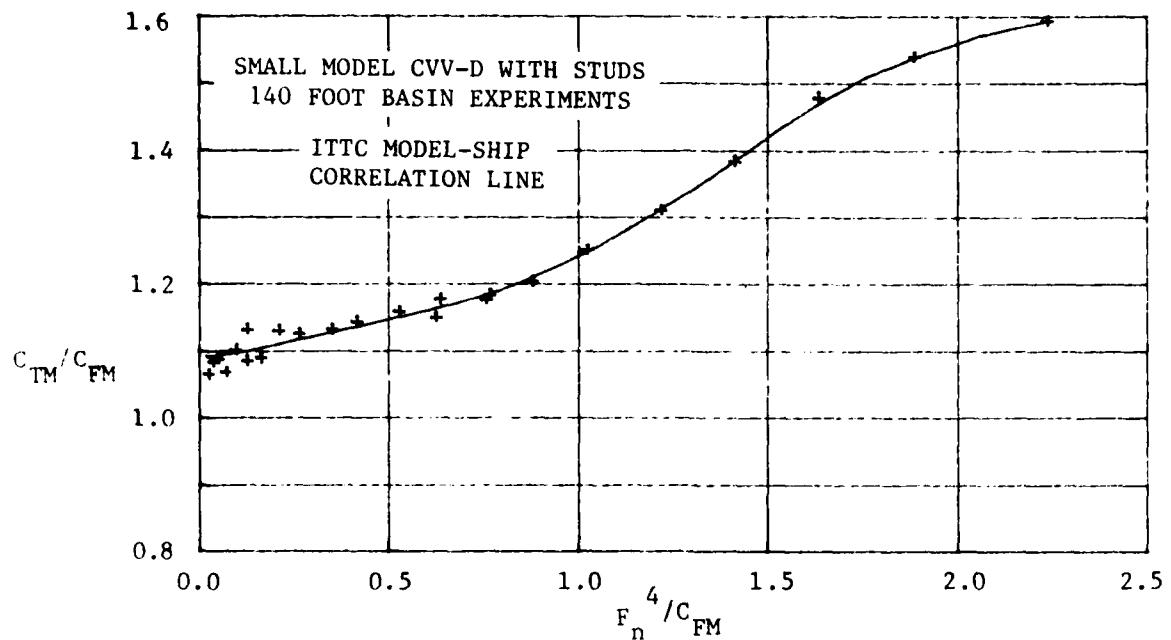


FIGURE 22 - PROHASKA PLOTS FOR THE SMALL CVV-D MODEL FROM  
THE 140 FOOT BASIN EXPERIMENTS

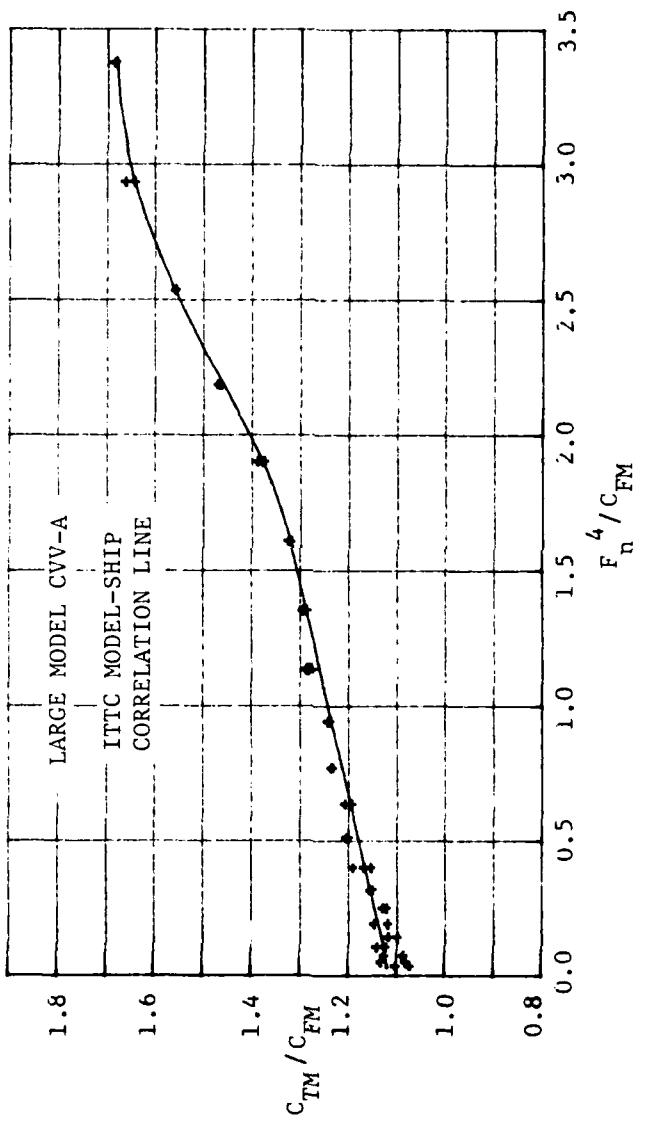


FIGURE 23 - PROHASKA PLOT FOR THE LARGE CVV-A MODEL

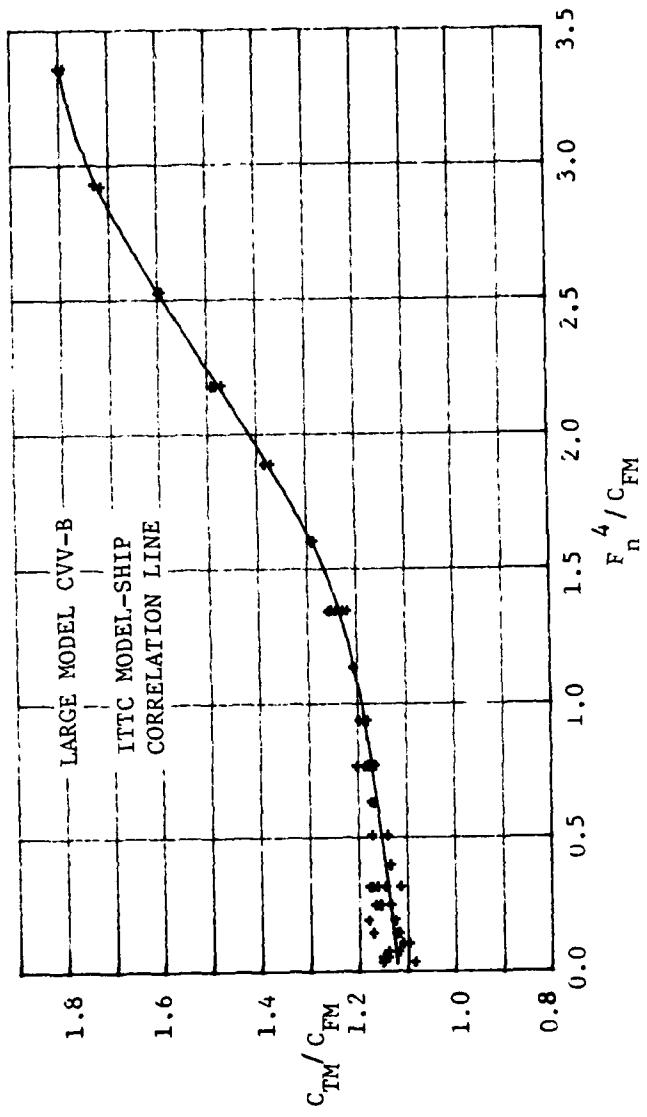


FIGURE 24 - PROHASKA PLOT FOR THE LARGE CVV-B MODEL

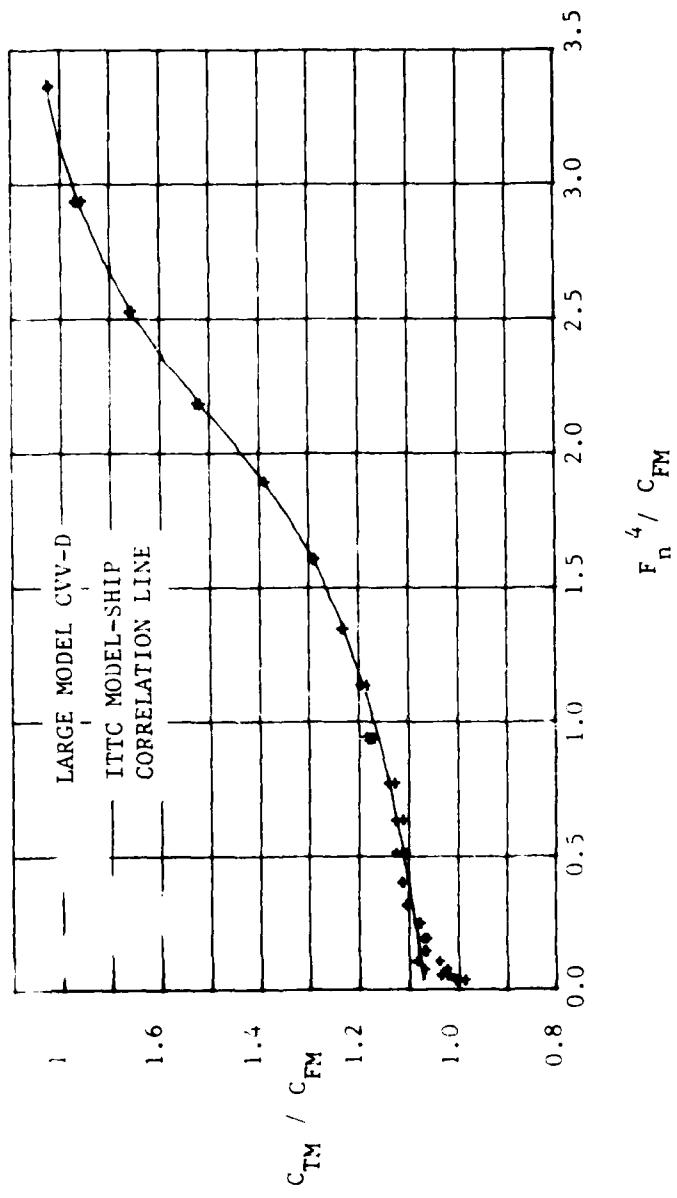


FIGURE 25 - PROHASKA PLOT FOR THE LARGE CVV-D MODEL

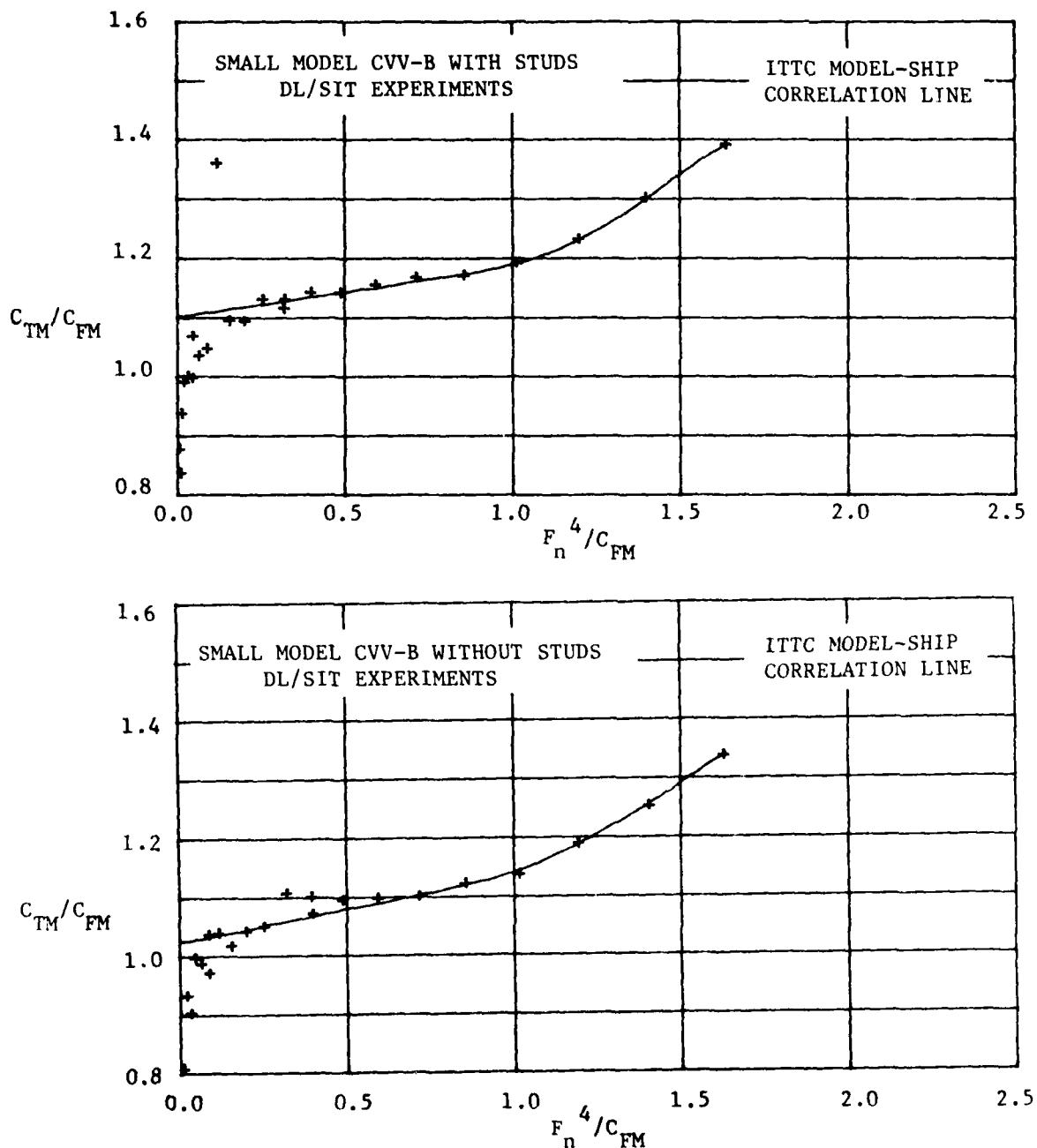


FIGURE 26 - PROHASKA PLOTS FOR THE SMALL CVV-B MODEL FROM DL/SIT

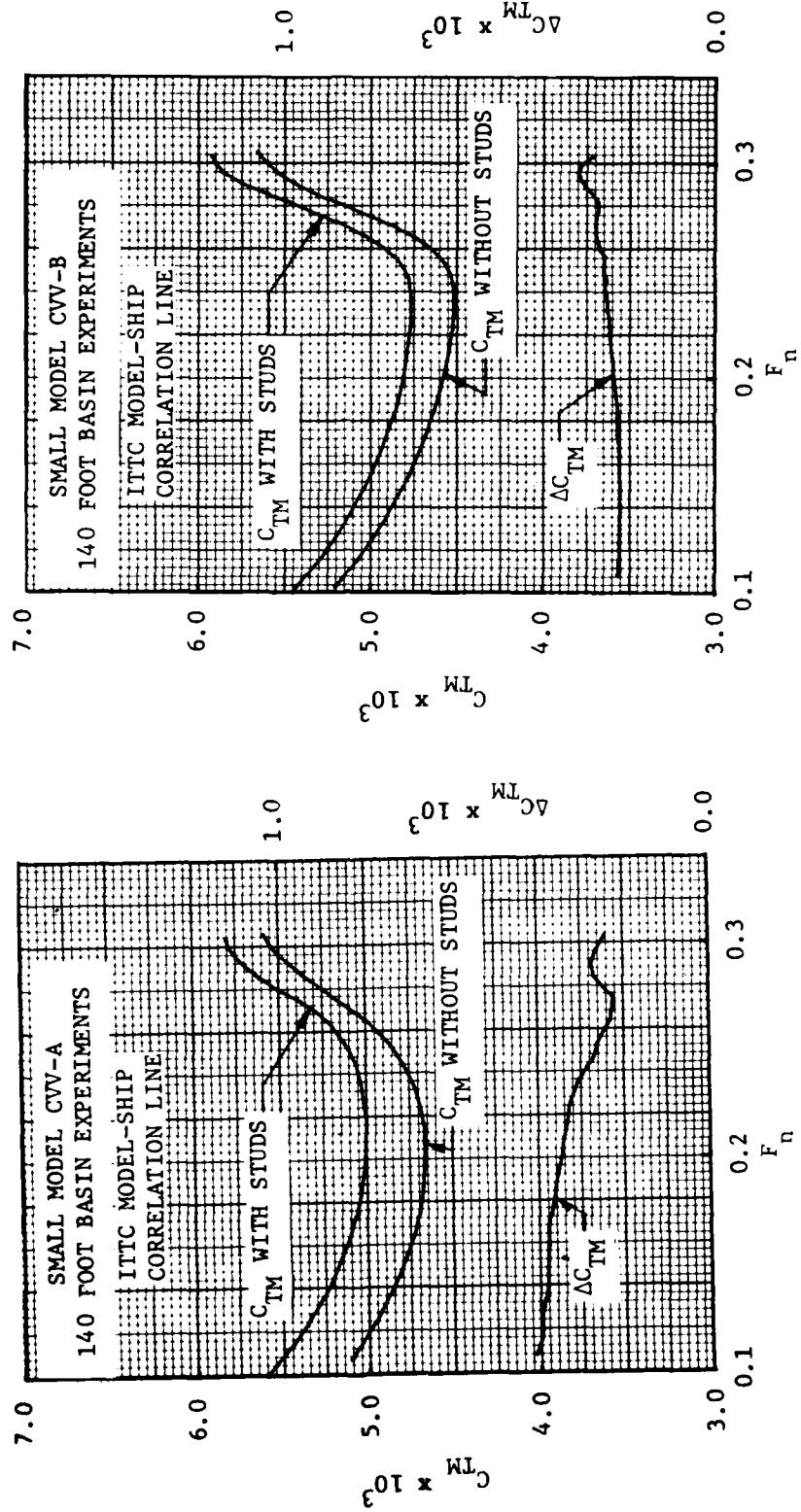


FIGURE 27 - TOTAL RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-A MODEL

FIGURE 28 - TOTAL RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-B MODEL

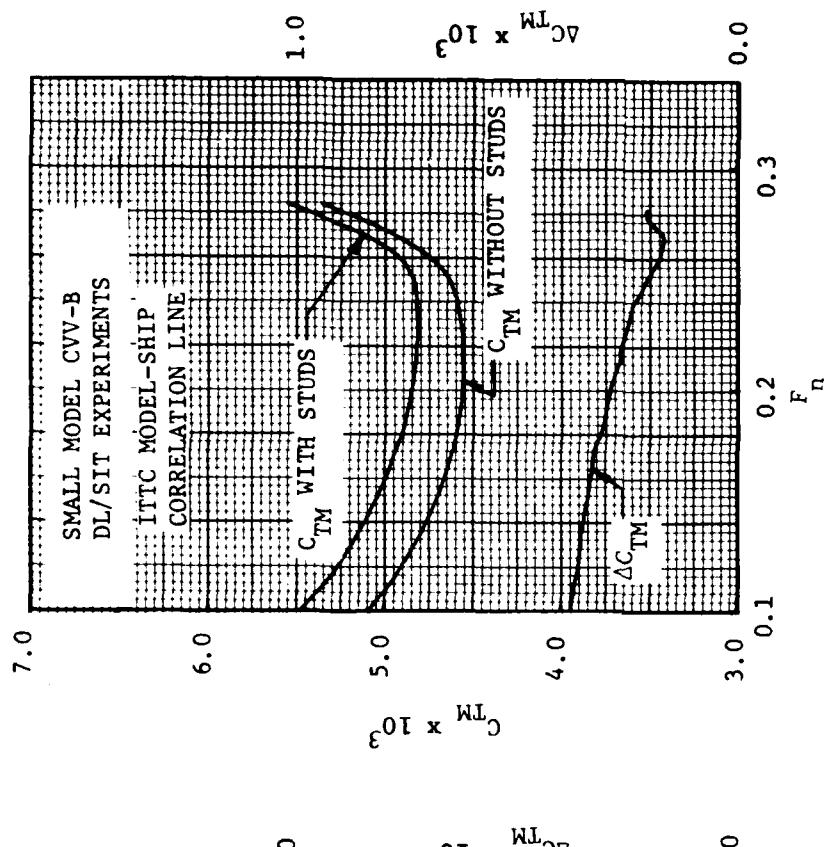
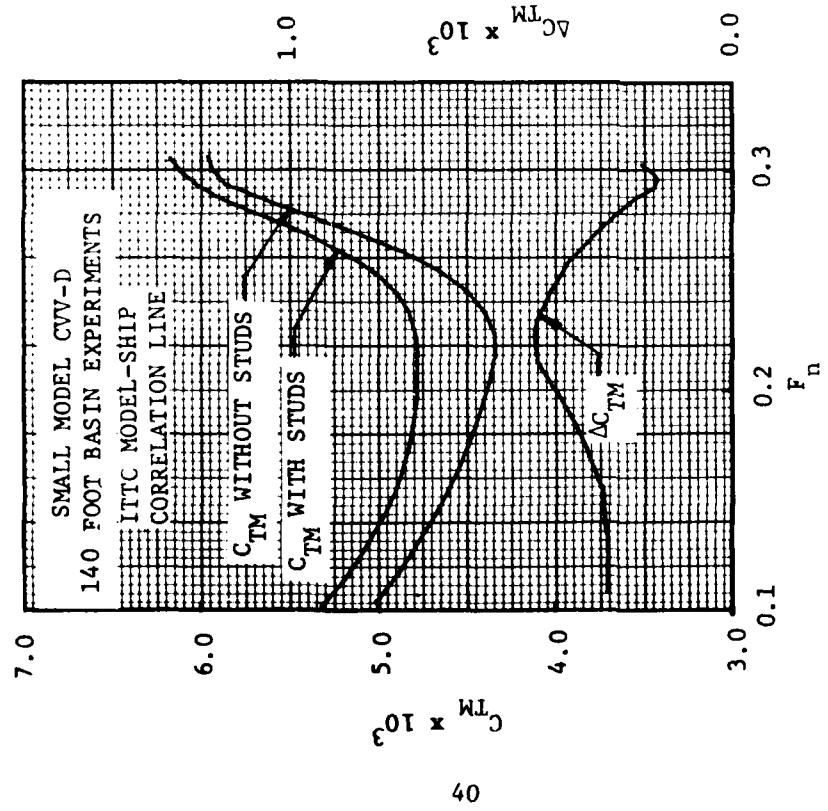


FIGURE 29 - TOTAL RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-D MODEL

FIGURE 30 - TOTAL RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-B MODEL FROM DL/SIT

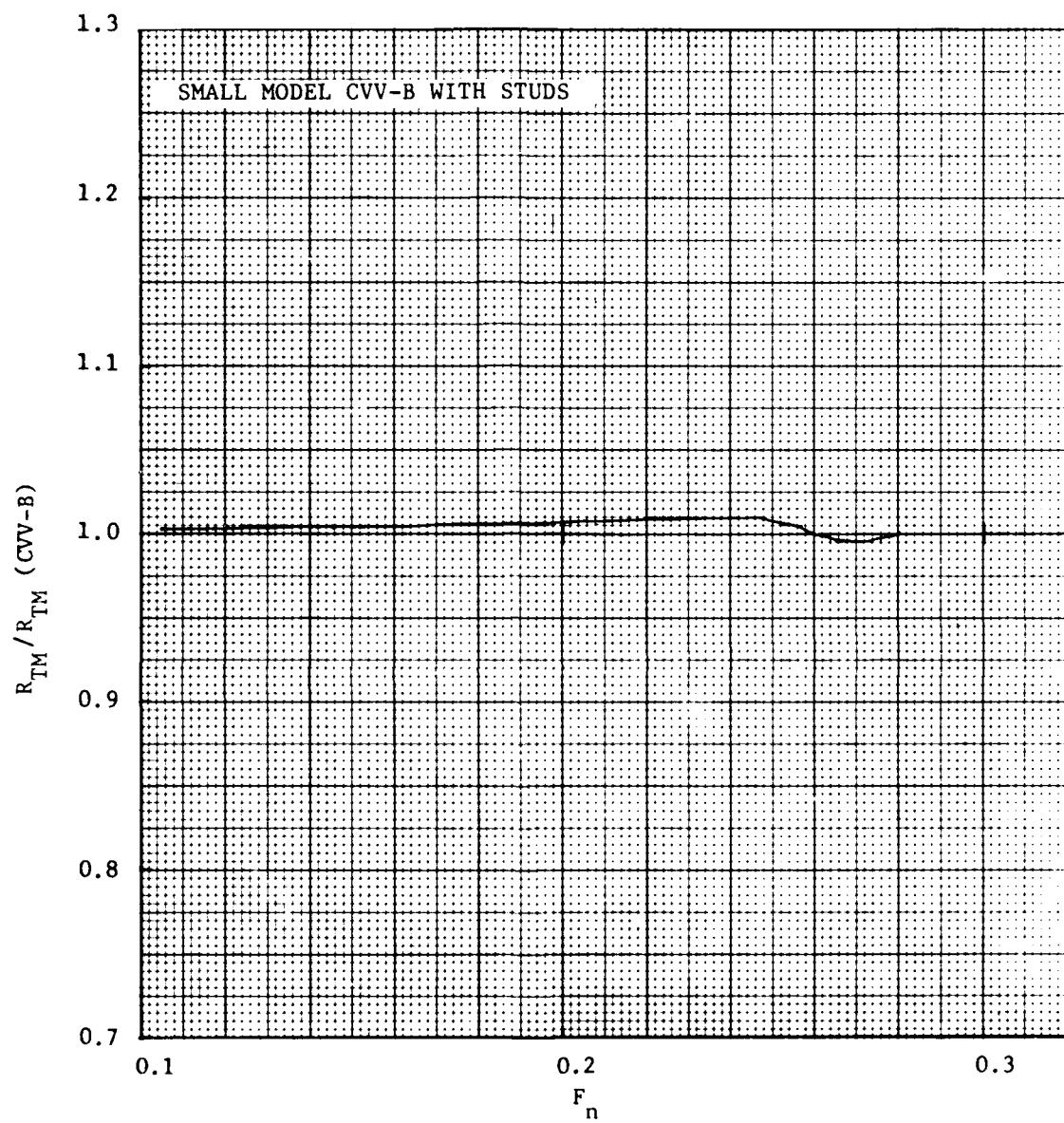


FIGURE 31 - R<sub>TM</sub> (DL/SIT) / R<sub>TM</sub> (DTNSRDC) FOR THE SMALL CVV-B MODEL

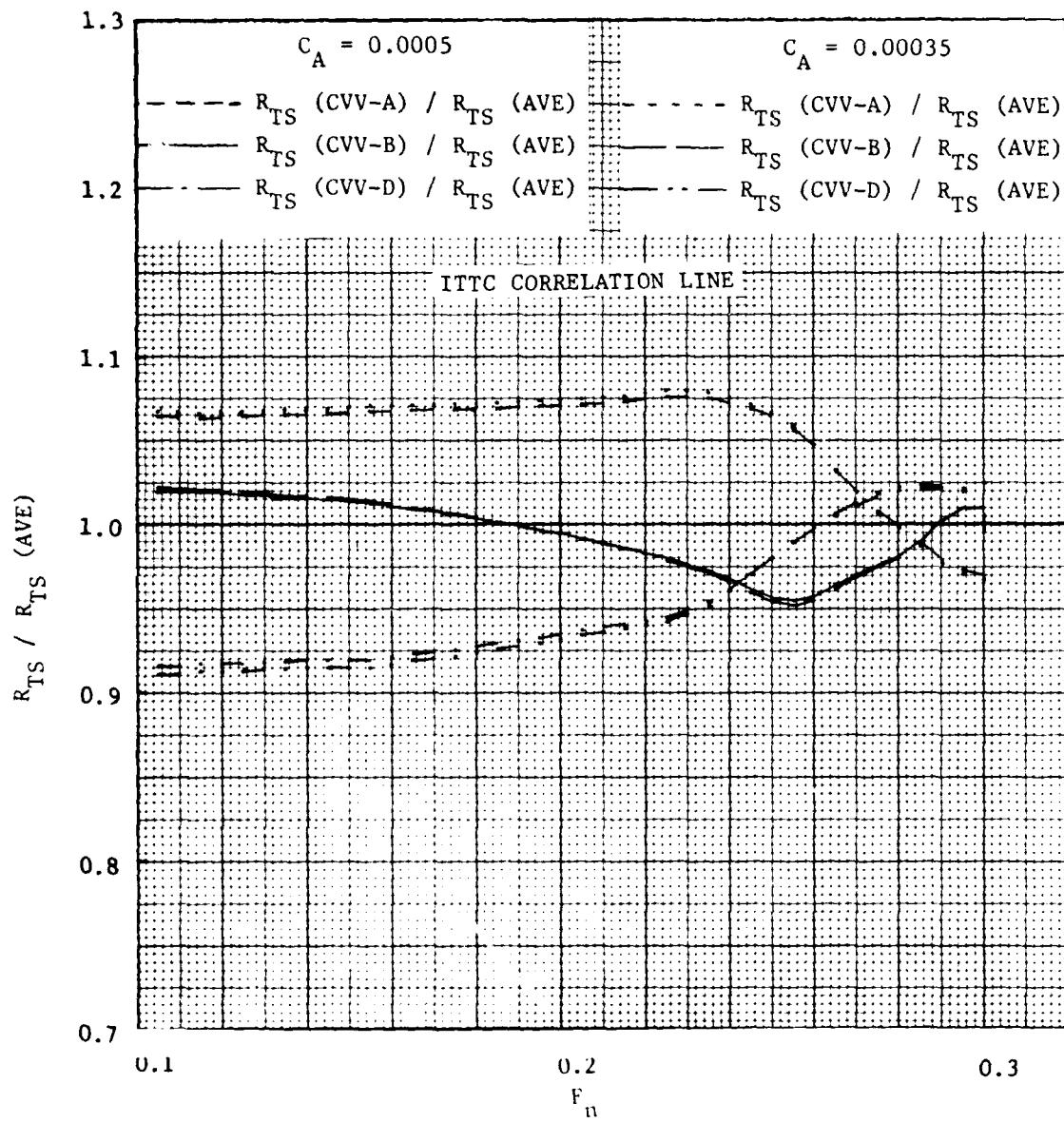


FIGURE 32 -  $R_{TS} / R_{TS}$  (AVE) VERSUS FROUDE NUMBER FOR THE SMALL CVV MODELS  
FROM THE 140 FOOT BASIN EXPERIMENTS

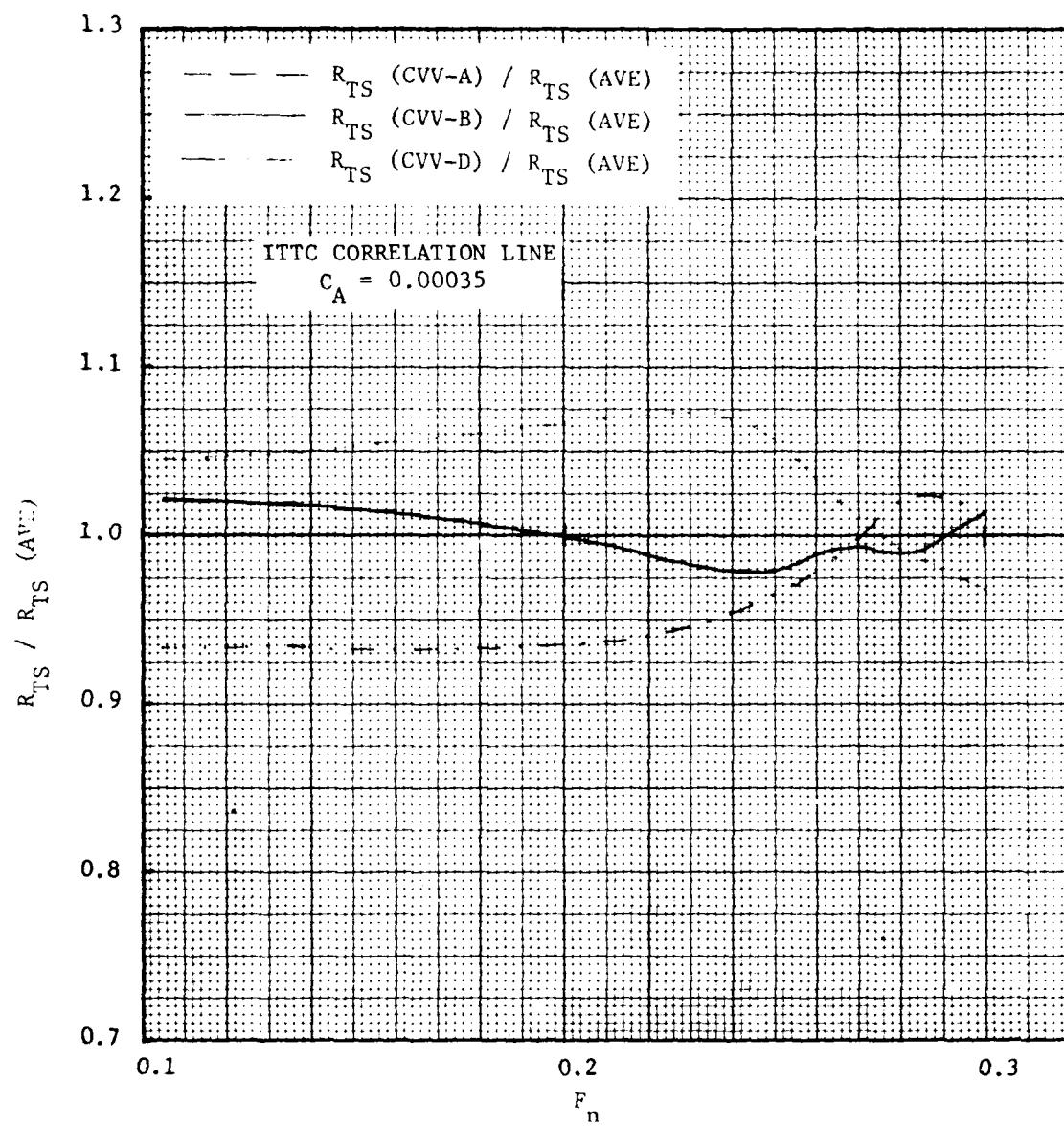


FIGURE 33 -  $R_{TS} / R_{TS} (\text{AVE})$  VERSUS FROUDE NUMBER FOR THE LARGE CVV MODELS

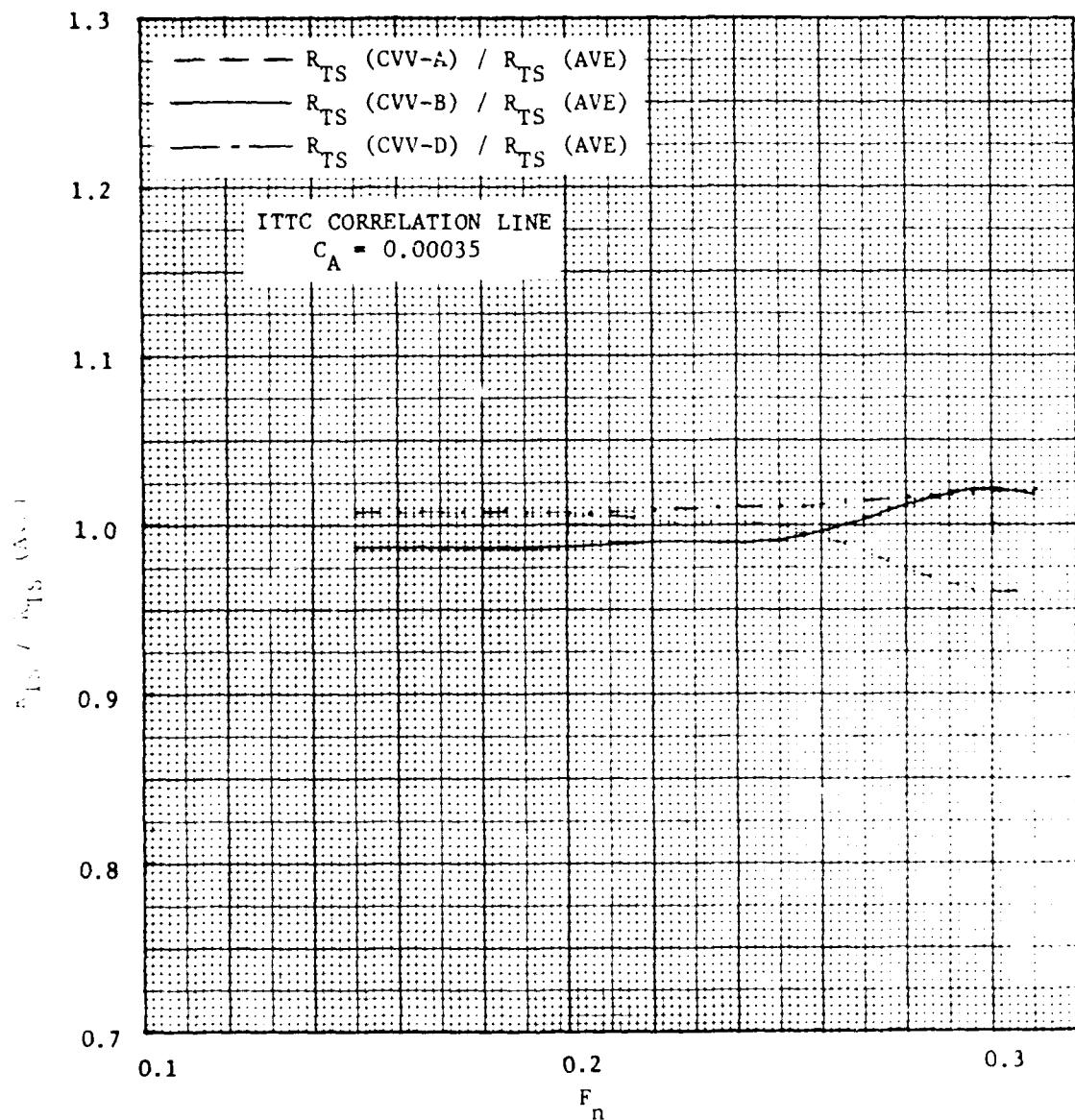


FIGURE 34 -  $R_{TS} / R_{TS} (\text{AVE})$  VERSUS FROUDE NUMBER USING TAYLOR STANDARD SERIES PREDICTIONS

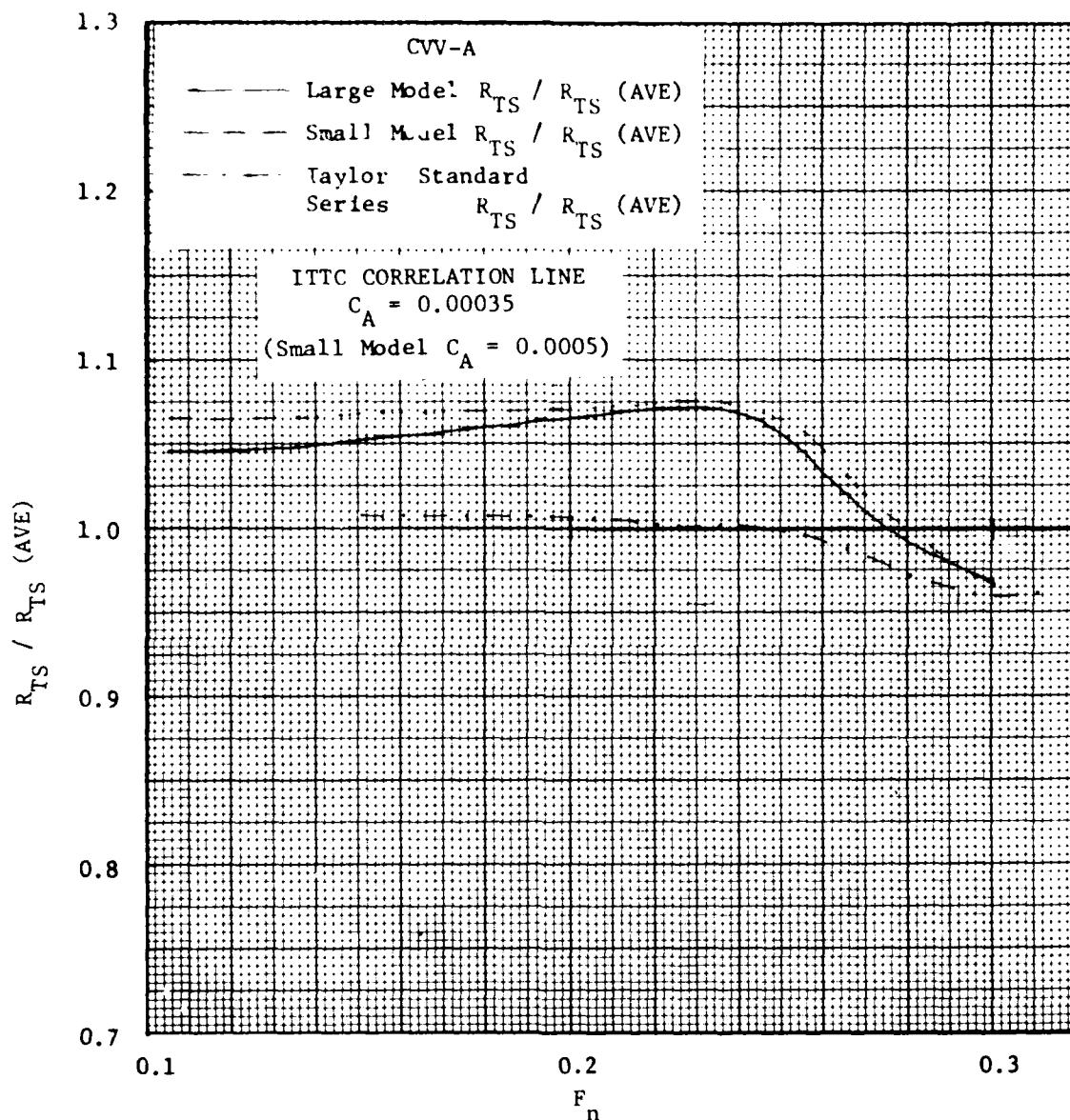


FIGURE 35 -  $R_{TS} / R_{TS}$  (AVE) VERSUS FROUDE NUMBER FOR CVV-A

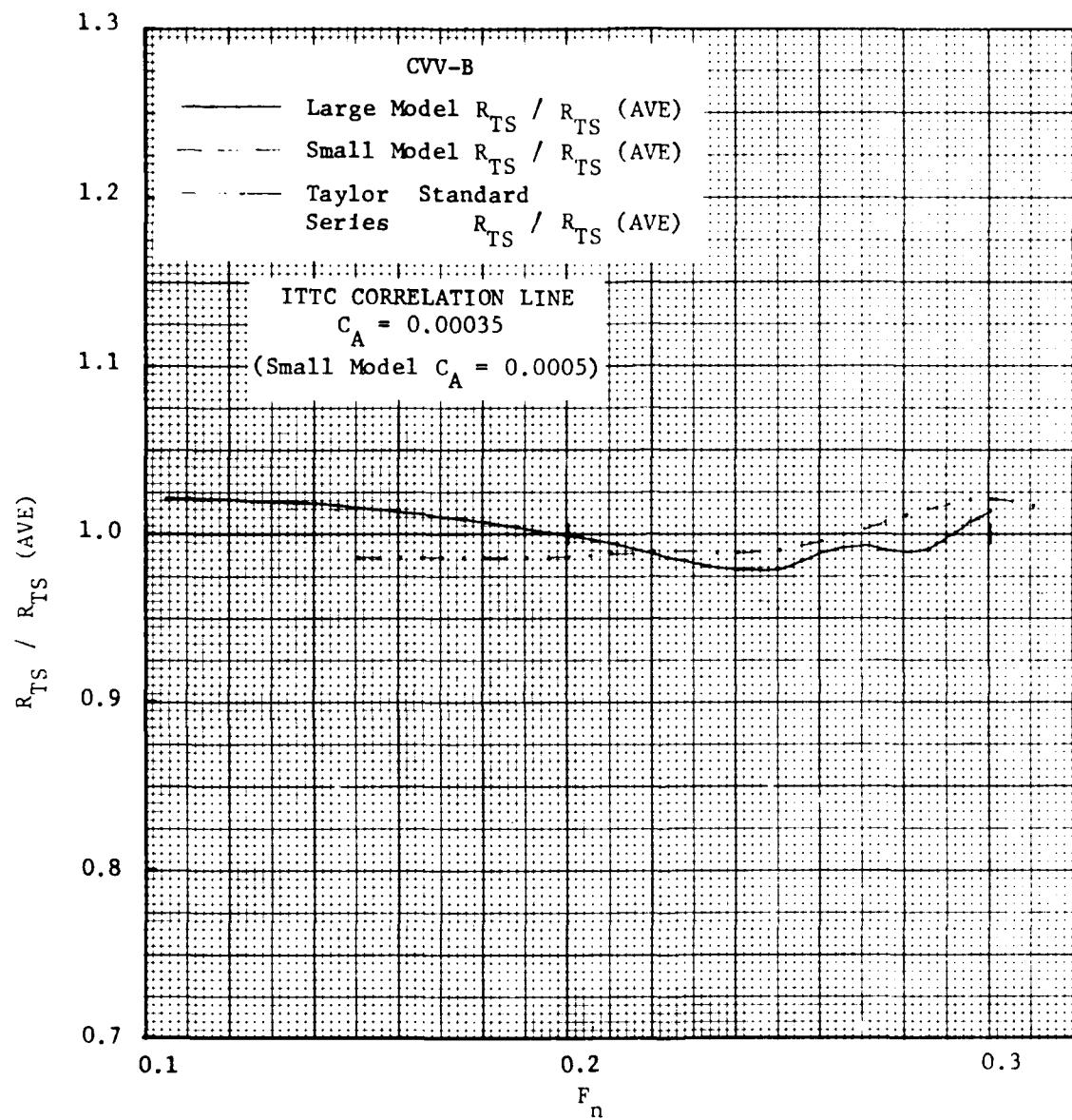


FIGURE 36 -  $R_{TS} / R_{TS}$  (AVE) VERSUS FROUDE NUMBER FOR CVV-B

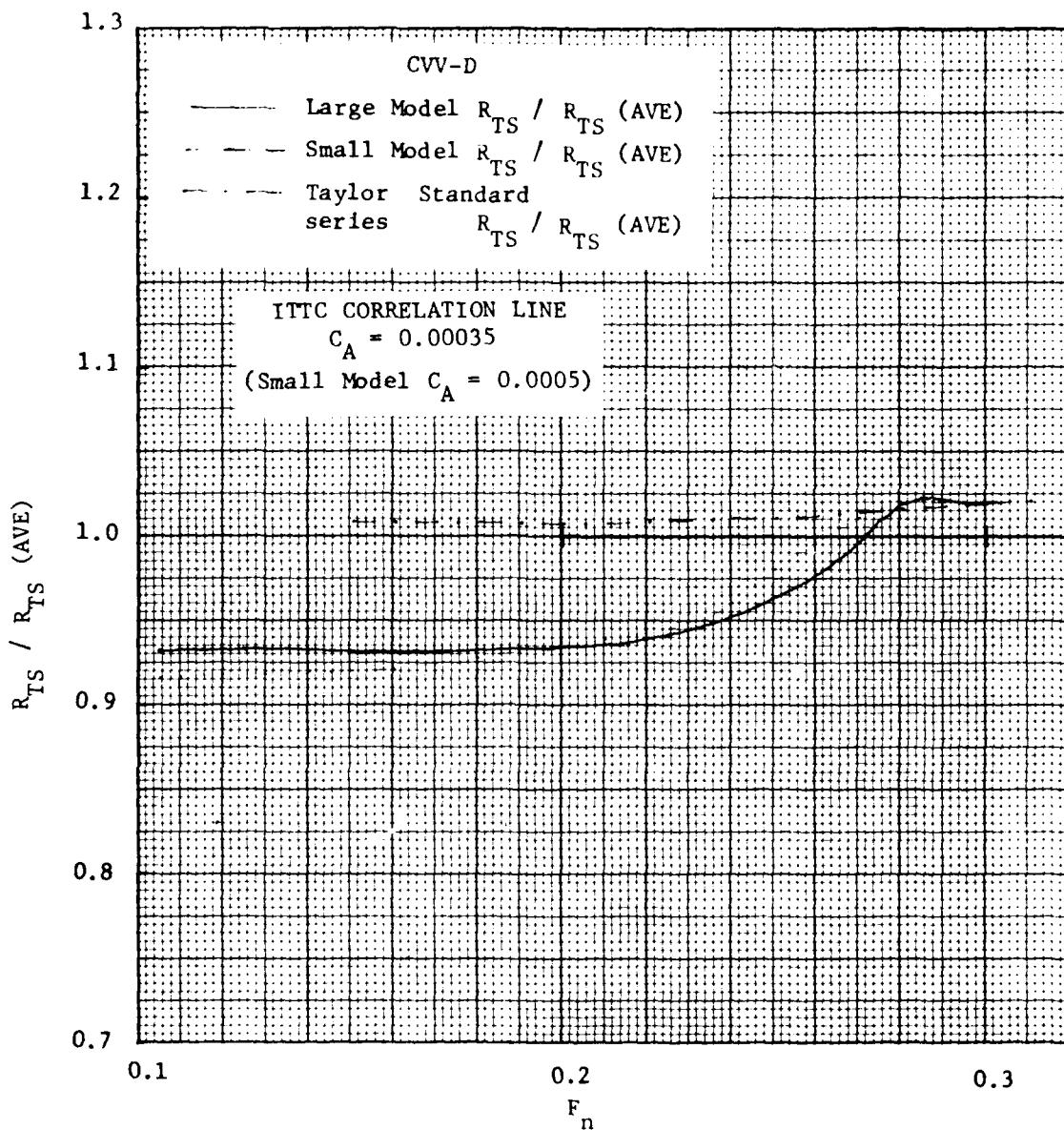


FIGURE 37 -  $R_{TS} / R_{TS} \text{ (AVE)}$  VERSUS FROUDE NUMBER FOR CVV-D

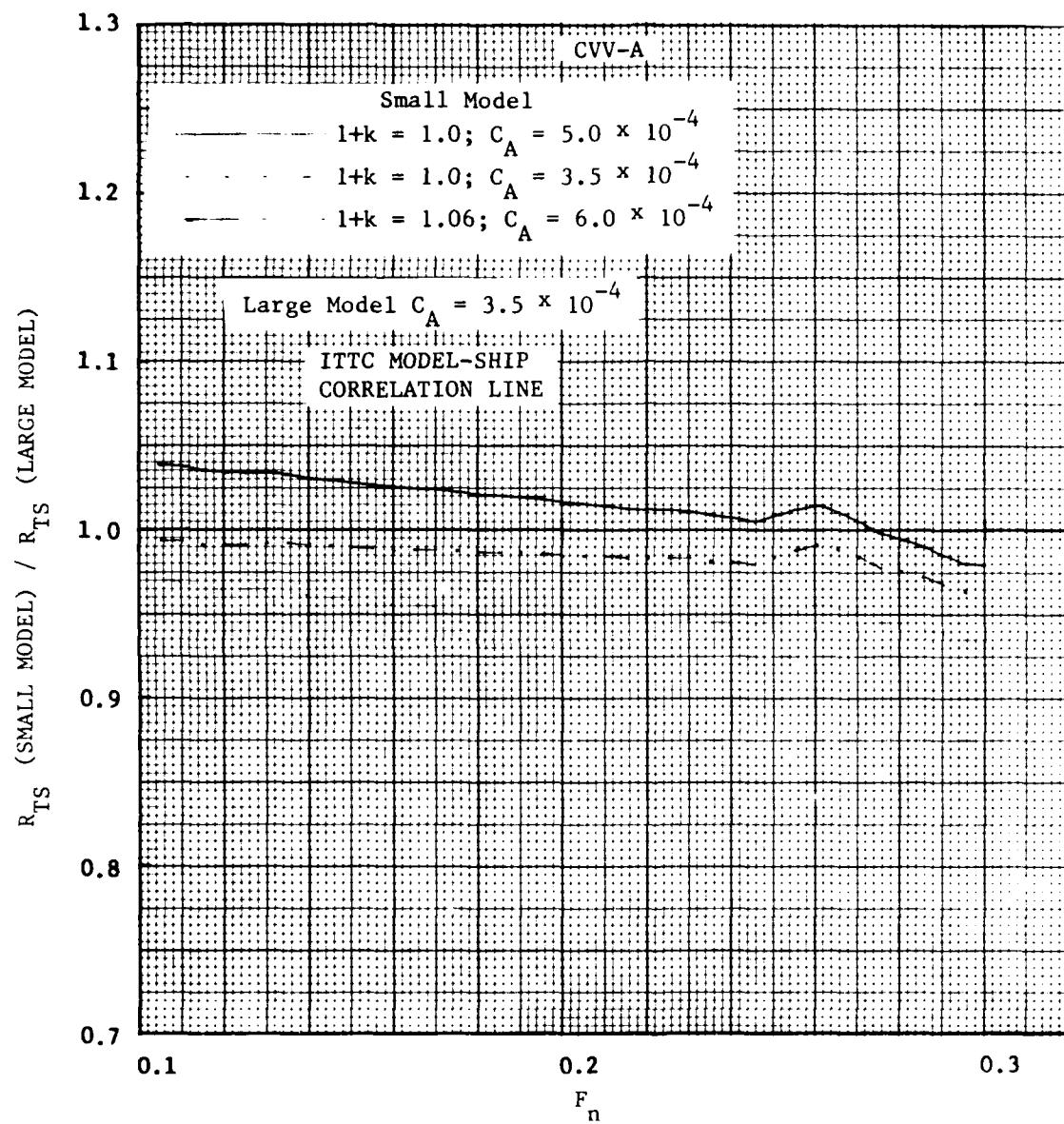


FIGURE 38 -  $R_{TS}$  (SMALL MODEL) /  $R_{TS}$  (LARGE MODEL) FOR THE CVV-A MODELS

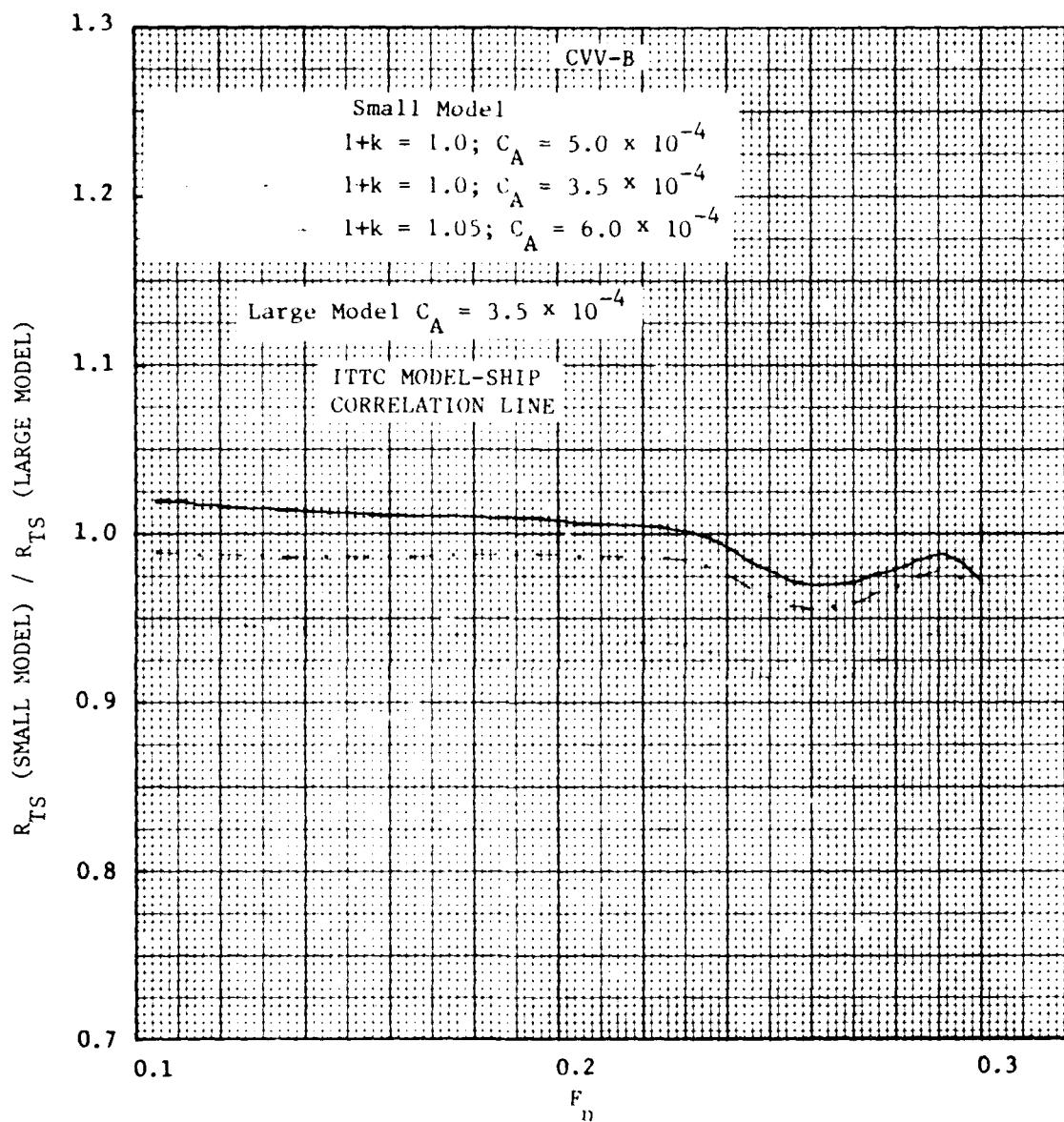


FIGURE 39 -  $R_{TS}$  (SMALL MODEL) /  $R_{TS}$  (LARGE MODEL) FOR THE CVV-B MODELS

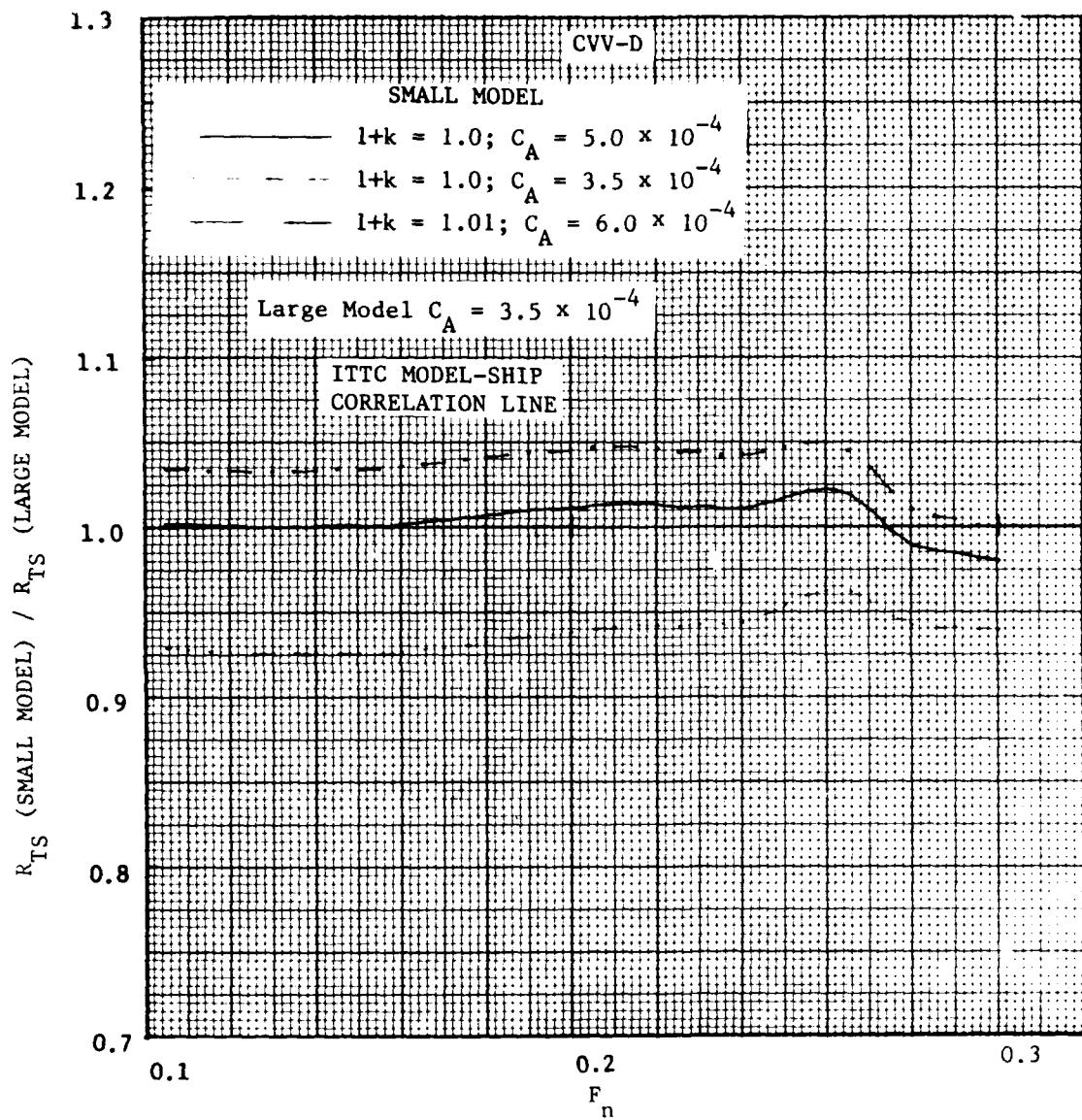


FIGURE 40 -  $R_{TS}$  (SMALL MODEL) /  $R_{TS}$  (LARGE MODEL) FOR THE CVV-D MODELS

TABLE 1  
PRINCIPAL DIMENSIONS OF SHIPS AND MODELS

SHIP	MODEL		MODEL
	$\lambda = 31.435$	$\lambda = 144$	
CVV - B			
LENGTH	262.1 m (860 ft)	8.34 m (27.36 ft)	1.82 m (5.97 ft)
BEAM	38.4 m (126 ft)	1.22 m (4.01 ft)	0.27 m (0.88 ft)
DRAFT	10.36 m (34 ft)	0.33 m (1.08 ft)	0.072 m (0.236 ft)
WETTED SURFACE	10470 m <sup>2</sup> (112700 ft <sup>2</sup> )	10.60 m <sup>2</sup> (114.1 ft <sup>2</sup> )	0.51 m <sup>2</sup> (5.436 ft <sup>2</sup> )
DISPLACEMENT	63430 t (62430 L tons)	1985 kg (4377 lbs)	20.7 kg (45.6 lbs)
CVV - A			
LENGTH	262.1 m (860 ft)	8.34 m (27.36 ft)	1.82 m (5.97 ft)
BEAM	38.4 m (126 ft)	1.22 m (4.01 ft)	0.27 m (0.88 ft)
DRAFT	10.36 m (34 ft)	0.33 m (1.08 ft)	0.072 m (0.236 ft)
WETTED SURFACE	10780 m <sup>2</sup> (116050 ft <sup>2</sup> )	10.91 m <sup>2</sup> (117.4 ft <sup>2</sup> )	0.52 m <sup>2</sup> (5.597 ft <sup>2</sup> )
DISPLACEMENT	63430 t (62430 L tons)	1985 kg (4377 lbs)	20.7 kg (45.6 lbs)
CVV - D			
LENGTH	262.1 m (860 ft)	8.34 m (27.36 ft)	1.82 m (5.97 ft)
BEAM	38.4 m (126 ft)	1.22 m (4.01 ft)	0.27 m (0.88 ft)
DRAFT	10.52 m (34.5 ft)	0.33 m (1.10 ft)	0.073 m (0.240 ft)
WETTED SURFACE	10620 m <sup>2</sup> (114340 ft <sup>2</sup> )	10.75 m <sup>2</sup> (115.7 ft <sup>2</sup> )	0.51 m <sup>2</sup> (5.514 ft <sup>2</sup> )
DISPLACEMENT	62970 t (61980 L tons)	1971 kg (4345 lbs)	20.5 kg (45.2 lbs)

TABLE 2 - UNFAIRRED RESISTANCE DATA FOR THE SMALL CVV-A MODEL WITHOUT STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

POINT	FROUDE NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR. CFM VALUES		1.9352 SLUGS/FT <sup>3</sup>	
		DENSITY 997.4 KG/M <sup>3</sup>		0.9307E-6 M <sup>2</sup> /S	
		5.97 FT	5.597 FT <sup>2</sup>	KINEMATIC 0.9307E-6 M <sup>2</sup> /S	1.0018E-5 FT <sup>2</sup> /S
LENGTH WETTED SURFACE	VS (M/S)	VS (KNOTS)	VM (M/S)	VM (FT/SEC)	VM (LBS)
POINT	VS (M/S)	VS (KNOTS)	VM (M/S)	VM (FT/SEC)	VM (LBS)
1	0.223	11.33	22.03	0.944	3.098
2	0.225	11.41	22.18	0.951	3.120
3	0.286	14.52	28.22	1.210	3.969
4	0.234	11.87	23.07	0.989	3.245
5	0.106	5.37	10.44	0.447	1.468
6	0.106	5.37	10.44	0.447	1.468
7	0.125	6.32	12.29	0.527	1.729
8	0.145	7.35	14.28	0.612	2.009
9	0.164	8.33	16.19	0.694	2.277
10	0.184	9.34	18.15	0.778	2.553
11	0.206	10.43	20.27	0.869	2.851
12	0.224	11.38	22.11	0.948	3.110
13	0.244	12.38	24.07	1.032	3.386
14	0.264	13.39	26.03	1.116	3.661
15	0.286	14.52	28.23	1.210	3.970
16	0.306	15.49	30.12	1.291	4.236
17	0.154	7.80	15.17	0.650	2.133
18	0.174	8.83	17.16	0.735	2.413
19	0.195	9.90	19.25	0.825	2.708
20	0.214	10.87	21.14	0.906	2.973
21	0.234	11.86	23.06	0.988	3.243
22	0.254	12.87	25.02	1.073	3.519
23	0.274	13.90	27.02	1.159	3.801
24	0.296	15.02	29.20	1.252	4.107
25	0.296	15.01	29.18	1.251	4.104

TABLE 3 - UNFAIRRED RESISTANCE DATA FOR THE SMALL CUVVA MODEL WITH STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

POINT	FRONDE NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR. CFM VALUES			1.9352 SLUGS/FT <sup>3</sup>	1.997.4 KG/FT <sup>3</sup>	0.9307E-6 FT <sup>2</sup> /S	1.0018E-5 FT <sup>2</sup> /S	
		CFM							
		LENGTH WETTED SURFACE	VS (M/S)	VS (KNOTS)	VM (M/S)	VM (FT/SEC)	RT <sup>*</sup> (IN)	RT <sup>*</sup> (LBS)	CFM *1000
1	0.104	5.26	10.22	0.438	1.438	0.280	0.063	5.626	0.777
2	0.123	6.22	12.09	0.518	1.701	0.358	0.081	5.137	0.464
3	0.143	7.26	14.11	0.605	1.984	0.444	0.104	4.893	0.371
4	0.163	8.25	16.03	0.687	2.255	0.607	0.137	4.957	0.556
5	0.183	9.26	18.01	0.772	2.533	0.757	0.170	4.895	0.601
6	0.203	10.31	20.04	0.859	2.818	0.931	0.209	4.867	0.666
7	0.225	11.39	22.14	0.949	3.114	1.102	0.249	4.745	0.629
8	0.245	12.44	24.17	1.036	3.400	1.361	0.306	4.886	0.843
9	0.263	13.35	25.94	1.112	3.649	1.557	0.350	4.954	0.867
10	0.283	14.37	27.93	1.198	3.929	2.030	0.456	5.459	1.531
11	0.304	15.39	29.92	1.283	4.208	2.404	0.540	5.635	1.760
12	0.115	5.81	11.29	0.484	1.588	0.321	0.072	5.279	0.536
13	0.134	6.81	13.25	0.568	1.863	0.423	0.095	5.065	0.482
14	0.155	7.84	15.24	0.653	2.143	0.532	0.120	4.813	0.365
15	0.174	8.83	17.17	0.736	2.415	0.691	0.155	4.920	0.583
16	0.195	9.86	19.18	0.822	2.697	0.847	0.190	4.833	0.594
17	0.216	10.93	21.25	0.911	2.989	1.046	0.235	4.861	0.711
18	0.234	11.87	23.08	0.989	3.246	1.261	0.284	4.968	0.887
19	0.254	12.89	25.05	1.074	3.523	1.501	0.337	5.020	1.005
20	0.274	13.90	27.02	1.159	3.801	1.809	0.467	5.198	1.244
21	0.294	14.91	28.99	1.243	4.077	2.211	0.497	5.521	1.622
22	0.223	11.29	21.94	0.941	3.086	1.133	0.255	4.940	0.817
23	0.264	13.40	26.05	1.117	3.664	1.625	0.365	5.026	1.043
24	0.284	14.41	28.02	1.201	3.941	2.039	0.459	5.451	1.525
25	0.296	15.03	29.21	1.252	4.168	2.254	0.507	5.545	1.652

TABLE 4 - UNFAIRED RESISTANCE DATA FOR THE SMALL Cvv-B MODEL WITHOUT STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

POINT FROUDE NUMBER	LTTIC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES		DENSITY KINETIC VISCOSEY	1.9352 SLUGS/FT <sup>3</sup> 0.930E-6 M <sup>-2</sup> /S 1.0018E-5 FT <sup>-2</sup> /S						
	1.820 M 0.505 M <sup>-2</sup>	5.97 FT 5.436 FT <sup>-2</sup>								
	VS (M/S)	VS (KNOTS)								
1	0.112	5.67	11.02	0.472	1.550	0.277	0.062	4.30	0.161	4.769
2	0.112	5.69	11.06	0.474	1.556	0.255	0.060	4.672	-0.093	4.765
3	0.132	6.68	12.99	0.557	1.827	0.389	0.088	4.984	0.382	4.602
4	0.133	6.72	13.06	0.560	1.837	0.383	0.086	4.851	0.254	4.596
5	0.152	7.72	15.00	0.643	2.110	0.467	0.105	4.484	0.021	4.462
6	0.153	7.74	15.04	0.645	2.116	0.479	0.108	4.577	0.118	4.460
7	0.172	8.70	16.91	0.725	2.378	0.620	0.139	4.683	0.332	4.352
8	0.171	8.68	16.87	0.723	2.373	0.165	0.037	1.253	-3.101	4.353
9	0.193	9.80	19.05	0.817	2.680	0.800	0.180	4.762	0.517	4.248
10	0.212	10.76	20.92	0.897	2.942	0.915	0.206	4.520	0.356	4.164
11	0.233	11.81	22.95	0.984	3.228	1.112	0.250	4.560	0.473	4.086
12	0.252	12.80	24.88	1.066	3.499	1.298	0.292	4.533	0.513	4.020
13	0.275	13.92	27.06	1.160	3.806	1.675	0.377	4.943	0.990	3.953
14	0.295	14.96	29.08	1.247	4.090	2.158	0.485	5.513	1.616	3.897
15	0.102	5.18	10.06	0.431	1.415	0.215	0.048	4.586	-0.279	4.866
16	0.103	5.22	10.15	0.435	1.428	0.215	0.048	4.503	-0.353	4.856
17	0.123	6.22	12.09	0.518	1.701	0.299	0.067	4.416	-0.258	4.673
18	0.123	6.25	12.14	0.521	1.708	0.293	0.066	4.288	-0.381	4.669
19	0.143	7.23	14.05	0.602	1.976	0.433	0.097	4.738	0.213	4.525
20	0.143	7.25	14.10	0.604	1.983	0.448	0.101	4.873	0.352	4.522
21	0.162	8.19	15.93	0.633	2.240	0.536	0.120	4.562	0.156	4.406
22	0.162	8.21	15.96	0.634	2.245	0.501	0.113	4.251	-0.153	4.404
23	0.182	9.24	17.95	0.770	2.525	0.750	0.169	5.031	0.733	4.297
24	0.182	9.24	17.97	0.770	2.527	0.644	0.156	4.647	0.351	4.297
25	0.203	10.28	19.98	0.856	2.810	0.819	0.195	4.702	0.499	4.203
26	0.223	11.28	21.93	0.940	3.045	1.112	0.228	4.545	0.421	4.124
27	0.242	12.29	23.69	1.024	3.345	1.449	0.267	4.503	0.450	4.053
28	0.264	13.41	26.06	1.117	3.645	1.438	0.335	4.736	0.753	3.983
29	0.285	14.44	28.07	1.203	3.934	1.946	0.438	5.336	1.412	3.924
30	0.305	15.46	30.05	1.218	4.227	2.373	0.533	5.676	1.804	3.872
31	0.203	10.27	19.97	0.815	2.459	0.844	0.190	4.571	0.	4.204
32	0.162	8.23	15.99	0.510	2.452	0.542	0.131	4.920	0.517	4.403
33	0.163	8.25	16.03	0.517	2.555	0.504	0.127	4.737	0.337	4.400
34	0.265	13.42	26.09	1.418	3.673	1.538	0.346	4.884	0.902	3.982
35	0.286	14.46	28.15	1.207	3.940	1.950	0.445	5.397	1.476	3.922
36	0.255	12.91	25.09	1.076	3.523	1.314	0.295	4.510	0.496	4.013

TABLE 5 - UNFAILED RESISTANCE DATA FOR THE SMALL CUV-B MODEL WITH STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

POINT	FROUDE NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES				CFM *1000			
		LENGTH WETTED SURFACE	1.820 0.505 M <sup>-2</sup>	5.97 FT	5.436 FT <sup>-2</sup>	KINEMATIC VISCOSEITY RTM (N)	RTM (LBS)		
1	0.104	5.27	10.24	0.439	1.440	0.230	0.052	4.749	-0.098
2	0.125	6.36	12.36	0.530	1.738	0.342	0.077	4.846	0.195
3	0.146	7.38	14.35	0.615	2.018	0.476	0.107	5.000	0.495
4	0.166	8.41	16.35	0.701	2.300	0.588	0.132	4.755	0.373
5	0.185	9.39	18.25	0.782	2.567	0.744	0.167	4.827	0.544
6	0.206	10.43	20.27	0.869	2.851	0.909	0.204	4.781	0.590
7	0.225	11.43	22.22	0.953	3.125	1.099	0.247	4.811	0.697
8	0.246	12.46	24.22	1.038	3.407	1.289	0.290	4.747	0.705
9	0.265	13.45	26.14	1.121	3.677	1.541	0.347	4.872	0.892
10	0.285	14.47	28.13	1.206	3.957	2.061	0.463	5.627	1.704
11	0.303	15.36	29.86	1.280	4.200	2.429	0.546	5.885	2.008
12	0.116	5.87	11.41	0.489	1.605	0.299	0.067	4.960	0.227
13	0.136	6.89	13.40	0.575	1.885	0.414	0.093	4.981	0.410
14	0.156	7.92	15.39	0.660	2.164	0.545	0.123	4.973	0.535
15	0.176	8.92	17.33	0.743	2.438	0.694	0.156	4.993	0.664
16	0.196	9.95	19.34	0.829	2.720	0.844	0.190	4.875	0.643
17	0.216	10.97	21.32	0.914	2.998	1.015	0.228	4.827	0.679
18	0.236	11.96	23.25	0.997	3.270	1.208	0.272	4.829	0.754
19	0.256	12.98	25.24	1.082	3.550	1.432	0.322	4.858	0.849
20	0.278	14.08	27.37	1.173	3.850	1.837	0.413	5.297	1.353
21	0.295	14.97	29.09	1.247	4.092	2.292	0.515	5.850	1.953
22	0.266	13.49	26.23	1.124	3.689	1.622	0.365	5.095	1.117

TABLE 5 - UNFAIRRED RESISTANCE DATA FOR THE SMALL CUV-3 MODEL WITHOUT STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

POINT	FROUDE NUMBER	ITTC MODEL-SHIP CORRELATION LINE		USED FOR CR, CFM VALUES		CFM *1000
		LINE	USED FOR CR, CFM VALUES	DENSITY	997.4 KG/M <sup>3</sup>	
		DENSITY	0.9307E-6 FT <sup>-2</sup> /S	KINEMATIC VISCOSITY	1.9352 SLUGS/FT <sup>3</sup>	
LENGTH WETTED SURFACE	1.820 0.512 M <sup>2</sup>	5.97 5.514 FT <sup>2</sup>	5.514 FT <sup>2</sup>	RTM (N)	RTM (LBS)	CR *1000
POINT	VS (M/S)	VS (KNOTS)	VM (M/S)	VM (FT/SEC)	RTM (LBS)	CFM *1000
1	0.103	5.23	10.17	0.436	1.431	0.048
2	0.123	6.21	12.08	0.518	1.699	0.072
3	0.143	7.27	14.13	0.606	1.987	0.095
4	0.163	8.26	16.06	0.689	2.259	0.120
5	0.183	9.28	18.03	0.773	2.536	0.147
6	0.203	10.31	20.04	0.859	2.818	0.179
7	0.225	11.39	22.14	0.949	3.114	0.215
8	0.245	12.41	24.12	1.034	3.392	0.253
9	0.263	13.35	25.96	1.113	3.651	0.294
10	0.284	14.38	27.96	1.198	3.932	0.334
11	0.306	15.51	30.15	1.292	4.240	0.444
12	0.315	5.81	11.29	0.484	1.588	0.290
13	0.134	6.82	13.25	0.568	1.864	0.392
14	0.154	7.83	15.22	0.652	2.140	0.476
15	0.174	8.80	17.11	0.734	2.407	0.588
16	0.194	9.82	19.09	0.818	2.685	0.735
17	0.214	10.86	21.11	0.905	2.969	0.872
18	0.235	11.92	23.18	0.994	3.260	1.087
19	0.254	12.86	24.99	1.071	3.515	1.323
20	0.274	13.89	27.00	1.157	3.797	1.737
21	0.293	14.88	28.92	1.240	4.068	2.232
22	0.244	12.37	24.04	1.031	3.381	1.183
23	0.284	14.40	27.98	1.200	3.936	1.990
24	0.306	15.51	30.15	1.292	4.240	2.404
25	0.234	11.85	23.04	0.988	3.241	1.093
26	0.225	11.40	22.17	0.950	3.118	0.950

TABLE 7 - UNFAIRED RESISTANCE DATA FOR THE SMALL CVV-D MODEL WITH STUDS FROM THE 140 FOOT BASIN EXPERIMENTS

POINT FROUDE NUMBER	LENGTH WETTED SURFACE AREA (M <sup>2</sup> )	VS (M/S)	VS (KNOTS)	VM (M/S)	(FT/SEC)	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES			CFM CFM *1000	
						DENSITY KINEMATIC VISCOSITY	997.4 0.9307E-6 M <sup>-3</sup>	1.9352 SLUGS/FT <sup>-3</sup> 1.0018E-5 FT <sup>-2</sup> /S		
							RTM (LBS)	CTM (N)	CR *1000	
1	0.105	5.34	10.37	0.445	1.459	0.252	0.057	4.992	0.160	4.833
2	0.124	6.29	12.23	0.524	1.720	0.346	0.078	4.923	0.261	4.662
3	0.145	7.34	14.27	0.612	2.007	0.461	0.104	4.821	0.310	4.510
4	0.164	8.30	16.13	0.691	2.268	0.567	0.127	4.642	0.247	4.395
5	0.183	9.30	18.07	0.775	2.542	0.719	0.162	4.690	0.399	4.291
6	0.196	9.95	19.33	0.829	2.719	0.816	0.183	4.650	0.418	4.232
7	0.225	11.42	22.20	0.952	3.122	1.062	0.239	4.590	0.476	4.114
8	0.236	11.99	23.39	0.999	3.277	1.193	0.268	4.679	0.506	4.074
9	0.253	12.84	24.96	1.076	3.510	1.426	0.321	4.877	0.660	4.018
10	0.273	13.87	26.95	1.155	3.791	1.812	0.407	5.313	1.357	3.956
11	0.293	14.85	28.87	1.238	4.061	2.282	0.513	5.831	1.929	3.902
12	0.115	5.85	11.37	0.487	1.599	0.302	0.068	4.977	0.241	4.737
13	0.135	6.83	13.27	0.569	1.866	0.392	0.088	4.748	0.167	4.581
14	0.154	7.81	15.19	0.651	2.136	0.529	0.119	4.889	0.438	4.451
15	0.174	8.80	17.10	0.733	2.405	0.654	0.147	4.763	0.422	4.341
16	0.204	10.36	20.14	0.863	2.833	0.887	0.200	4.659	0.463	4.196
17	0.216	10.97	21.33	0.914	3.000	0.996	0.224	4.665	0.517	4.147
18	0.244	12.38	24.07	1.032	3.385	1.286	0.289	4.729	0.682	4.047
19	0.264	13.38	26.01	1.115	3.659	1.610	0.362	5.066	1.082	3.984
20	0.283	14.35	27.90	1.196	3.924	2.061	0.463	5.641	1.712	3.929
21	0.305	15.47	30.07	1.289	4.229	2.541	0.571	5.986	2.115	3.871
22	0.154	7.82	15.19	0.651	2.137	0.508	0.114	4.683	0.232	4.450
23	0.226	11.47	22.30	0.956	3.136	1.096	0.246	4.696	0.586	4.110
24	0.236	11.96	23.24	0.996	3.269	1.180	0.265	4.653	0.577	4.076

POINT	FROUDE NUMBER	VS (M/S)	VS (KNOTS)	VA (M/S)	VM (FT/SEC)	RTM (IN)	RTM (LBS)	ITTC WHEEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES		1.9352 SLUGS/FT <sup>3</sup> 1.0018E-5 FT <sup>-2</sup> , S	
								DENSITY	997.4 KG/M <sup>3</sup>		
1	0.103	5.24	10.19	0.935	3.069	15.771	3.546	3.314	0.220	3.094	
2	0.103	5.24	10.19	0.935	3.069	16.212	3.645	3.406	0.312	3.002	
3	0.123	6.23	12.11	1.111	3.645	21.850	4.912	3.255	0.252	3.002	
4	0.123	6.23	12.11	1.111	3.645	22.643	5.091	3.373	0.371	3.002	
5	0.143	7.27	14.13	1.237	4.254	20.339	6.596	3.209	0.285	2.923	
6	0.143	7.27	14.14	1.237	4.256	29.868	6.715	3.263	0.340	2.923	
7	0.164	8.30	16.13	1.480	4.855	38.150	8.577	3.203	0.345	2.853	
8	0.164	8.30	16.13	1.480	4.855	38.414	8.636	3.225	0.367	2.804	
9	0.183	9.29	18.06	1.657	5.436	48.194	10.835	3.228	0.424	2.804	
10	0.183	9.29	18.06	1.657	5.436	48.811	10.974	3.269	0.465	2.804	
11	0.205	10.38	20.17	1.851	6.073	61.850	13.905	3.319	0.566	2.753	
12	0.205	10.37	20.17	1.850	6.071	61.057	13.727	3.279	0.526	2.753	
13	0.225	11.40	22.17	2.034	6.673	75.683	17.015	3.364	0.654	2.710	
14	0.225	11.40	22.16	2.033	6.671	75.331	16.936	3.350	0.640	2.710	
15	0.245	12.43	24.16	2.217	7.272	92.423	20.779	3.459	0.787	2.672	
16	0.245	12.43	24.16	2.217	7.274	91.806	20.640	3.434	0.762	2.672	
17	0.266	13.50	26.23	2.497	7.897	114.450	25.731	3.632	0.996	2.636	
18	0.266	13.50	26.23	2.497	7.897	114.185	25.671	3.624	0.987	2.636	
19	0.266	13.50	26.23	2.497	7.897	115.419	25.948	3.663	1.027	2.636	
20	0.285	14.46	28.10	2.578	8.459	146.785	33.000	4.060	1.453	2.607	
21	0.285	14.46	28.11	2.579	8.461	146.696	32.980	4.056	1.449	2.607	
22	0.285	14.46	28.10	2.578	8.459	146.785	33.000	4.060	1.453	2.607	
23	0.306	15.49	30.11	2.763	9.064	179.912	40.448	4.334	1.756	2.578	
24	0.305	15.49	30.10	2.762	9.062	180.089	40.488	4.340	1.762	2.578	
25	0.113	5.72	11.12	1.020	3.346	19.471	4.378	3.442	0.394	3.048	
26	0.113	5.72	11.12	1.020	3.346	18.590	4.179	3.286	0.239	3.048	
27	0.133	6.76	13.13	1.205	3.954	26.256	5.903	3.324	0.363	2.960	
28	0.133	6.76	13.14	1.205	3.955	26.696	6.002	3.378	0.417	2.960	
29	0.154	7.79	15.15	1.390	4.560	33.921	7.626	3.229	0.340	2.889	
30	0.154	7.79	15.15	1.390	4.560	34.802	7.824	3.312	0.424	2.889	
31	0.173	8.79	17.08	1.567	5.141	43.436	9.765	3.253	0.422	2.831	
32	0.173	8.78	17.07	1.566	5.139	43.612	9.805	3.268	0.437	2.831	
33	0.194	9.85	19.14	1.756	5.761	55.859	12.558	3.331	0.554	2.777	
34	0.194	9.84	19.13	1.755	5.759	55.947	12.578	3.339	0.561	2.777	
35	0.214	10.87	21.12	1.938	6.358	68.899	15.490	3.373	0.641	2.732	
36	0.214	10.87	21.12	1.938	6.358	68.723	15.450	3.365	0.633	2.732	
37	0.235	11.92	23.18	2.127	6.978	84.758	19.055	3.445	0.755	2.690	
38	0.235	11.92	23.18	2.127	6.977	85.022	19.115	3.457	0.766	2.690	
39	0.235	11.92	23.18	2.127	6.978	84.317	18.956	3.427	0.737	2.690	
40	0.256	12.96	25.19	2.311	7.583	102.115	22.957	3.515	0.861	2.654	
41	0.256	12.96	25.18	2.311	7.581	101.546	22.839	3.498	0.844	2.654	
42	0.275	13.96	27.13	2.489	8.166	129.340	29.078	3.839	1.217	2.622	
43	0.275	13.96	27.13	2.489	8.166	129.868	29.197	3.854	1.232	2.622	
44	0.194	9.84	19.13	1.755	5.759	55.771	12.538	3.328	0.551	2.777	
45	0.194	9.84	19.12	1.755	5.757	55.947	12.578	3.341	0.563	2.777	

TABLE 6 - UNFAIR ED PREDICTION DATA FOR THE LARGE CVA-MODEL (CONTINUED)

SURFACE POINT	FREQUENCY NUMBER	VISIBILITY		RTA (LBS)	CTW *1000	CR *1000
		VS (N.S.)	VS (N.S.)			
1	0.103	5.23	10.17	0.943	3.560	0.465
2	0.103	5.23	10.16	0.933	3.354	0.258
3	0.122	6.21	12.07	1.108	3.634	3.096
4	0.123	6.21	12.08	1.103	2.203	3.004
5	0.143	7.25	14.09	1.203	2.424	3.004
6	0.143	7.25	14.09	1.203	3.020	2.924
7	0.143	7.25	14.09	1.203	2.937	2.924
8	0.163	8.27	16.08	1.476	4.842	2.860
9	0.163	8.27	16.08	1.476	4.842	2.860
10	0.183	9.27	18.02	1.654	5.425	2.805
11	0.183	9.27	18.02	1.654	5.426	2.805
12	0.204	10.36	20.13	1.847	6.050	2.754
13	0.204	10.36	20.13	1.847	6.060	2.754
14	0.225	11.38	22.13	2.030	6.651	2.711
15	0.225	11.38	22.13	2.030	6.661	2.711
16	0.225	11.38	22.13	2.030	6.651	2.711
17	0.245	12.41	24.12	2.213	7.262	2.673
18	0.245	12.41	24.12	2.213	7.262	2.673
19	0.266	13.47	26.18	2.402	7.882	2.637
20	0.266	13.47	26.19	2.403	7.984	2.637
21	0.245	14.45	28.09	2.577	8.456	2.607
22	0.285	14.45	28.09	2.577	8.456	2.607
23	0.285	14.45	28.08	2.577	8.454	2.607
24	0.163	8.28	16.69	1.476	4.844	2.859
25	0.163	8.28	16.69	1.476	4.844	2.859
26	0.305	15.47	30.07	2.753	6.052	2.579
27	0.305	15.47	30.07	2.753	6.052	2.579
28	0.113	5.71	11.10	1.018	3.341	3.048
29	0.113	5.71	11.10	1.018	3.339	3.048
30	0.133	6.75	13.12	1.204	3.949	3.048
31	0.133	6.75	13.12	1.204	3.649	3.048
32	0.153	7.73	15.11	1.387	4.550	3.251
33	0.153	7.73	15.11	1.387	4.548	3.251
34	0.173	8.77	17.04	1.543	5.129	3.329
35	0.173	8.77	17.04	1.543	5.129	3.329
36	0.194	9.83	19.11	1.754	5.754	3.315
37	0.194	9.83	19.11	1.754	5.754	3.315
38	0.214	10.85	21.10	1.950	6.626	3.315
39	0.214	10.85	21.10	1.950	6.626	3.315
40	0.235	11.91	23.16	2.125	6.472	3.242
41	0.235	11.91	23.15	2.124	6.470	3.243
42	0.255	12.94	25.16	2.389	7.574	3.243
43	0.255	12.95	25.17	2.389	7.575	3.243
44	0.275	13.91	27.11	2.477	8.150	2.662
45	0.275	13.91	27.10	2.477	8.150	2.662

TABLE 9 - UNFAIRED RESISTANCE DATA FOR THE LARGE CVV-B MODEL

(CONTINUED)

POINT	SURFACE FROUDE NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES					
		LENGTH WETTED	8.339 10.597	M <sup>2</sup> M <sup>2</sup>	27.36 114.070	FT <sup>2</sup> FT <sup>2</sup>	997.4 0.9307E-6
							KG/M <sup>3</sup> M <sup>2</sup> /S
		VS (M/S)	VS (KNOTS)	VM (M/S)	VM (FT/SEC)	RTM (N)	RTM (LBS)
46	0.275	13.95	27.11	2.438	8.162	125.992	28.325
47	0.245	12.41	24.12	2.213	7.262	85.361	19.550
48	0.245	12.42	24.13	2.214	7.265	86.636	19.491
49	0.245	12.41	24.12	2.213	7.262	85.903	19.313
50	0.295	14.97	29.09	2.669	8.757	168.723	37.932
51	0.295	14.95	29.08	2.668	8.753	167.137	37.576
52	0.173	8.77	17.05	1.564	5.132	42.467	9.547
53	0.173	8.77	17.04	1.564	5.131	41.850	9.409
54	0.173	8.77	17.05	1.564	5.132	40.705	9.151
55	0.214	10.85	21.09	1.935	6.350	63.63	14.301
56	0.214	10.85	21.09	1.935	6.350	64.053	14.400
57	0.214	10.85	21.09	1.935	6.350	65.022	14.618
58	0.214	10.86	21.10	1.936	6.353	63.789	14.341
						*1000	*1000
						CFM	CFM

TABLE IV - REQUIRED RESISTANCE DATA FOR THE LARGE CROWN MODEL

POINT	FRONDE SURFACE NUMBER	LTC MODEL-SHIP CORRELATION LINE USED FOR CR. CFM VALUES				RTM (LBS)	CFM *1000
		VS (M/S)	VS (KNOTS)	V:1 (M/S)	FM (FT/SEC)		
1	0.103	5.24	10.18	0.934	3.065	14.273	3.209
2	0.103	5.24	10.18	0.934	3.065	14.537	3.209
3	0.123	6.22	12.09	1.109	3.639	20.264	4.556
4	0.123	6.22	12.09	1.109	3.638	2.145	4.754
5	0.143	7.26	14.10	1.254	4.245	28.618	6.299
6	0.143	7.26	14.10	1.254	4.246	27.930	6.279
7	0.163	8.28	16.09	1.477	4.845	35.947	8.082
8	0.163	8.28	16.09	1.477	4.845	36.123	8.121
9	0.183	9.27	18.02	1.654	5.426	45.727	10.280
10	0.183	9.28	18.04	1.655	5.430	45.903	10.320
11	0.204	10.36	20.14	1.848	6.063	56.828	12.776
12	0.204	10.36	20.14	1.848	6.063	55.947	12.578
13	0.225	11.38	22.13	2.031	6.662	70.651	15.886
14	0.225	11.39	22.14	2.031	6.664	70.220	15.787
15	0.245	12.42	24.13	2.214	7.265	86.696	19.491
16	0.245	12.42	24.13	2.214	7.265	86.432	19.432
17	0.266	13.48	26.20	2.404	7.887	113.304	25.473
18	0.266	13.48	26.20	2.404	7.887	113.481	25.513
19	0.285	14.45	28.08	2.576	8.453	154.274	34.684
20	0.285	14.45	28.08	2.577	8.454	153.745	34.565
21	0.305	15.47	30.08	2.760	9.054	191.983	43.162
22	0.305	15.48	30.08	2.760	9.056	191.933	43.162
23	0.113	5.71	11.10	1.018	3.341	17.269	3.882
24	0.113	5.71	11.09	1.018	3.339	17.533	3.942
25	0.133	6.75	13.12	1.204	3.950	23.877	5.368
26	0.133	6.75	13.12	1.204	3.949	24.934	5.606
27	0.153	7.78	15.11	1.387	4.550	31.806	7.151
28	0.153	7.76	15.11	1.387	4.550	31.630	7.111
29	0.173	8.77	17.05	1.564	5.132	41.057	9.231
30	0.173	8.77	17.05	1.564	5.132	40.831	9.191
31	0.194	9.84	19.12	1.755	5.757	50.749	11.409
32	0.194	9.84	19.12	1.755	5.757	51.542	11.588
33	0.214	10.86	21.11	1.937	6.355	62.027	13.945
34	0.214	10.86	21.11	1.937	6.355	62.731	14.103
35	0.235	11.92	23.16	2.125	6.973	77.181	17.352
36	0.235	11.92	23.16	2.125	6.973	77.954	17.530
37	0.255	12.95	25.17	2.310	7.578	97.974	22.026
38	0.256	12.96	25.18	2.311	7.581	97.728	21.987
39	0.275	13.25	27.11	2.438	8.162	132.159	29.712
40	0.275	13.25	27.11	2.438	8.162	132.776	29.851
41	0.295	14.25	27.11	2.438	8.162	15.747	3.170
42	0.295	14.25	27.11	2.438	8.162	15.645	3.426
43	0.225	15.25	22.13	2.630	9.041	15.645	3.426
44	0.225	15.25	22.13	2.630	9.041	15.645	3.426
45	0.295	17.25	24.12	2.811	9.841	39.458	1.316
46	0.295	17.25	24.11	2.811	9.841	39.558	1.337

TABLE 11 - UNFAIRED RESISTANCE DATA FOR THE SMALL CVV-B MODEL WITHOUT  
STUDS FROM THE D-51 EXPERIMENTS

POINT	FROUDE NUMBER	VS (M/S)	VS (KNOTS)	V: (M/S)	V: (FT/SEC)	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES		1.9365 SLUGS/FT <sup>3</sup>	1.0692E-5 FT <sup>-2</sup> /S		
						DENSITY	KINETIC VISCOSEITY				
1	0.061	3.08	5.99	0.257	0.843	0.071	0.016	4.278	-1.282		
2	0.071	3.60	7.00	0.300	0.984	0.089	0.020	3.924	-1.437		
3	0.081	4.11	8.00	0.343	1.125	0.125	0.028	4.203	-0.996		
4	0.091	4.63	8.99	0.395	1.265	0.142	0.032	3.799	-1.263		
5	0.101	5.14	10.00	0.429	1.406	0.214	0.048	4.613	-0.330		
6	0.112	5.65	10.99	0.471	1.546	0.245	0.055	4.372	-0.469		
7	0.122	6.17	11.99	0.514	1.687	0.316	0.071	4.749	-0.009		
8	0.132	6.68	12.99	0.557	1.827	0.360	0.081	4.610	-0.057		
9	0.142	7.19	13.99	0.600	1.967	0.431	0.097	4.763	0.170		
10	0.142	7.20	14.00	0.600	1.953	0.405	0.091	4.459	-0.133		
11	0.152	7.71	14.99	0.643	2.108	0.489	0.110	4.703	0.178		
12	0.162	8.23	16.00	0.686	2.250	0.538	0.121	4.541	0.078		
13	0.172	8.74	16.99	0.728	2.389	0.614	0.138	4.594	0.187		
14	0.182	9.25	17.98	0.771	2.529	0.685	0.154	4.575	0.220		
15	0.193	9.77	18.99	0.814	2.671	0.796	0.179	4.767	0.462		
16	0.203	10.28	19.98	0.856	2.810	0.867	0.195	4.692	0.432		
17	0.203	10.29	19.99	0.857	2.812	0.845	0.190	4.565	0.306		
18	0.213	10.89	21.00	0.900	2.953	0.943	0.212	4.619	0.402		
19	0.223	11.31	21.99	0.943	3.093	1.027	0.231	4.588	0.411		
20	0.233	11.83	23.00	0.986	3.235	1.116	0.251	4.557	0.418		
21	0.243	12.34	23.59	1.028	3.374	1.228	0.276	4.606	0.503		
22	0.254	12.86	24.99	1.071	3.515	1.339	0.301	4.629	0.559		
23	0.263	13.36	25.97	1.113	3.652	1.499	0.337	4.801	0.762		
24	0.274	13.89	27.00	1.157	3.797	1.695	0.381	5.021	1.014		
25	0.284	14.39	27.97	1.199	3.934	1.930	0.434	5.328	1.350		

TABLE 12 - AERODYNAMIC RESISTANCE DATA FOR THE STATION CVV-6 MODEL WITH  
STUDS FACING THE STREAMWISE WIND

POINT NUMBER	FRONTO- SURFACE NUMBER	LENGTH WETTED SURFACE	V <sub>S</sub> (M/S)	V <sub>T</sub> (M/SEC)	V <sub>H</sub> (FT/SEC)	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES		
						DENSITY KINETIC VISCOSEITY	CFM	CFM *1000
							RTM	RTW
1	0.061	1.820 0.505	3.06 5.97	5.99 5.436	0.257 FT <sup>2</sup>	0.843 0.984	0.016 0.024	4.278 4.709
2	0.071	3.60	7.00	8.00	0.300 0.343	0.107 0.125	0.024 0.029	-0.652 4.353
3	0.081	4.11			0.316	0.125	0.029	-0.845
4	0.091	4.63	8.99	9.99	1.265	0.178	0.040	-0.313
5	0.101	5.14	10.00	10.00	1.429	1.406	0.227	4.902
6	0.112	5.65	10.99	0.471	1.546	0.271	0.061	4.849
7	0.122	6.17	11.99	0.514	1.686	0.338	0.076	5.080
8	0.122	6.17	11.99	0.514	1.687	0.316	0.071	4.740
9	0.132	6.69	13.00	0.557	1.828	0.378	0.085	4.833
10	0.142	7.19	13.99	0.600	1.967	0.436	0.098	4.812
11	0.152	7.71	14.99	0.643	2.108	0.641	0.144	6.157
12	0.162	8.23	15.99	0.685	2.249	0.578	0.130	4.883
13	0.172	8.74	16.99	0.728	2.390	0.645	0.145	4.823
14	0.183	9.25	17.99	0.771	2.530	0.738	0.166	4.927
15	0.193	9.76	18.98	0.814	2.669	0.801	0.180	4.801
16	0.193	9.77	19.00	0.814	2.672	0.814	0.183	4.870
17	0.203	10.30	20.01	0.858	2.815	0.903	0.203	4.857
18	0.213	10.80	20.99	0.902	2.952	0.983	0.221	4.818
19	0.223	11.31	21.98	0.942	3.092	1.081	0.243	4.829
20	0.233	11.83	22.99	0.985	3.233	1.183	0.266	4.835
21	0.243	12.34	23.99	1.028	3.374	1.281	0.288	4.807
22	0.253	12.85	24.97	1.070	3.512	1.401	0.315	4.852
23	0.264	13.37	25.99	1.114	3.655	1.557	0.350	4.978
24	0.274	13.87	26.96	1.156	3.792	1.757	0.395	5.219
25	0.284	14.40	28.00	1.200	3.938	2.010	0.452	5.538

Table 13  
REPEATABILITY EXPERIMENTS

Froude Number	0.18	0.24	0.28
Model	Percentage Difference	Percentage Difference	Percentage Difference
CVV-A	3.1	2.5	3.0
CVV-B	2.8	3.1	2.2
CVV-D	2.6	3.4	3.5

Percentage difference is the maximum difference in the resistance values / mean resistance  $\times$  100.

Experiments were performed in the 140 Foot Basin at DTNSRDC with the small models.

## APPENDIX A

### SMALL MODEL DATA FROM THE DEEP WATER BASIN

A series of resistance experiments were performed in the Deep Water Basin with the small CVV models. Because of the small size of the models, the standard model towing system could not be used. The models were attached to the carriage through a vertical strut fastened to the top of the block gauge. The block gauge and a towing bracket were the same as used in the 140 Foot Basin experiments.

There were some problems with the small model resistance data, notably with CVV-D. Because of time constraints these difficulties were not resolved. Therefore, the small model CVV-D results from the Deep Water Basin are not presented in faired data-plots.

Figures A1 to A4 show the resistance data for the small CVV-A and CVV-B models. The data scatter is smaller than the scatter in the data from the 140 Foot Basin experiments because the sampling period is much longer, approximately 45 seconds. The resistance curves are faired using the residuary resistance coefficient curves (Figures A5 and A6) and the Prohaska plots (Figures A7 and A8).

Figure A9 shows the curves of  $R_{TM}$  (Deep Water basin)/ $R_{TM}$  (140 Foot Basin) for the CVV-A and CVV-B small models. Generally, the resistance values of the small models from the Deep Water Basin are within 1 1/2 percent of the 140 Foot Basin resistance values.

The unfaired data obtained in the Deep Water Basin for the small models are listed in Tables A1 through A6.

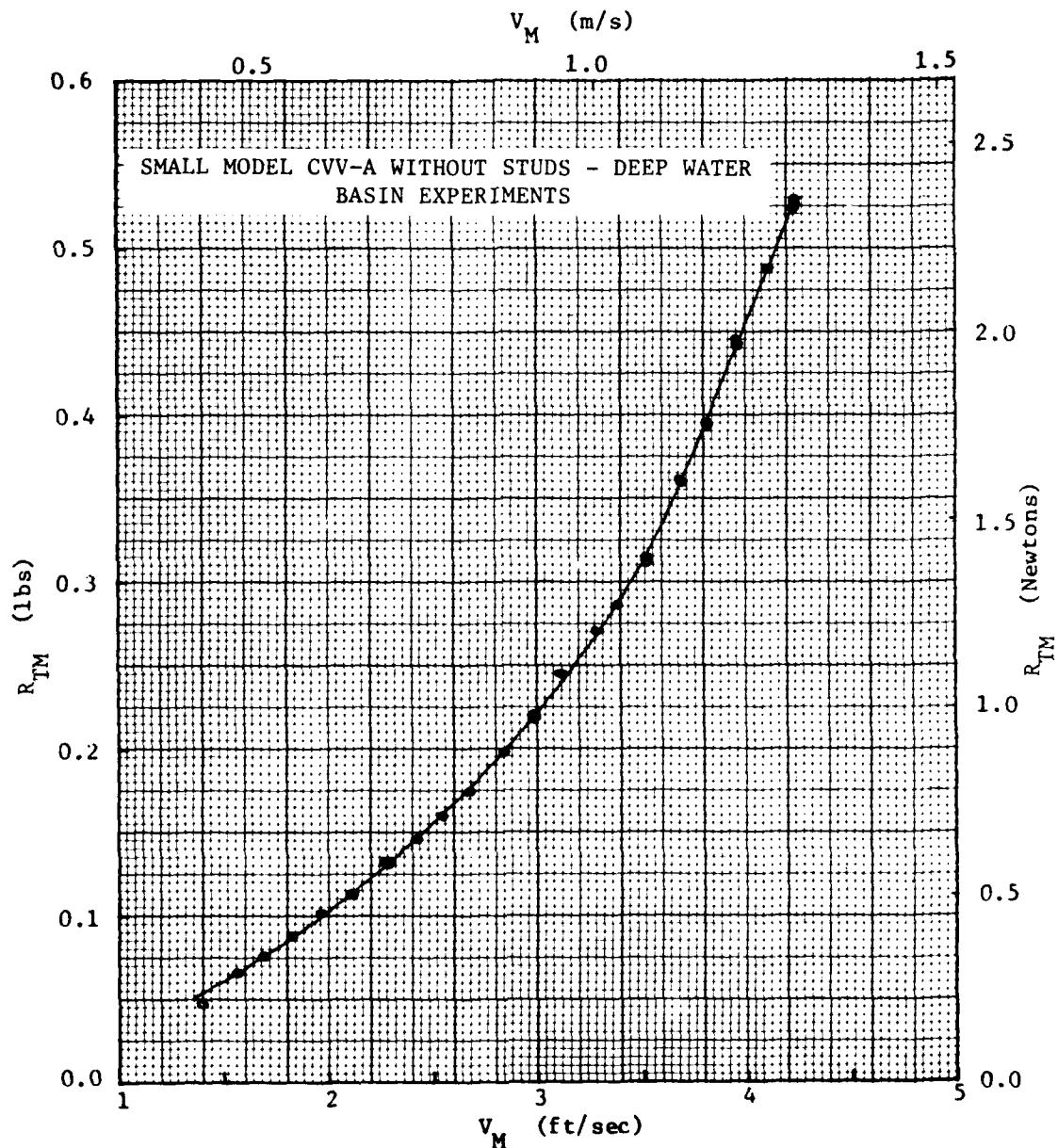


FIGURE A1 - RESISTANCE VALUES FOR THE SMALL CVV-A MODEL WITHOUT STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

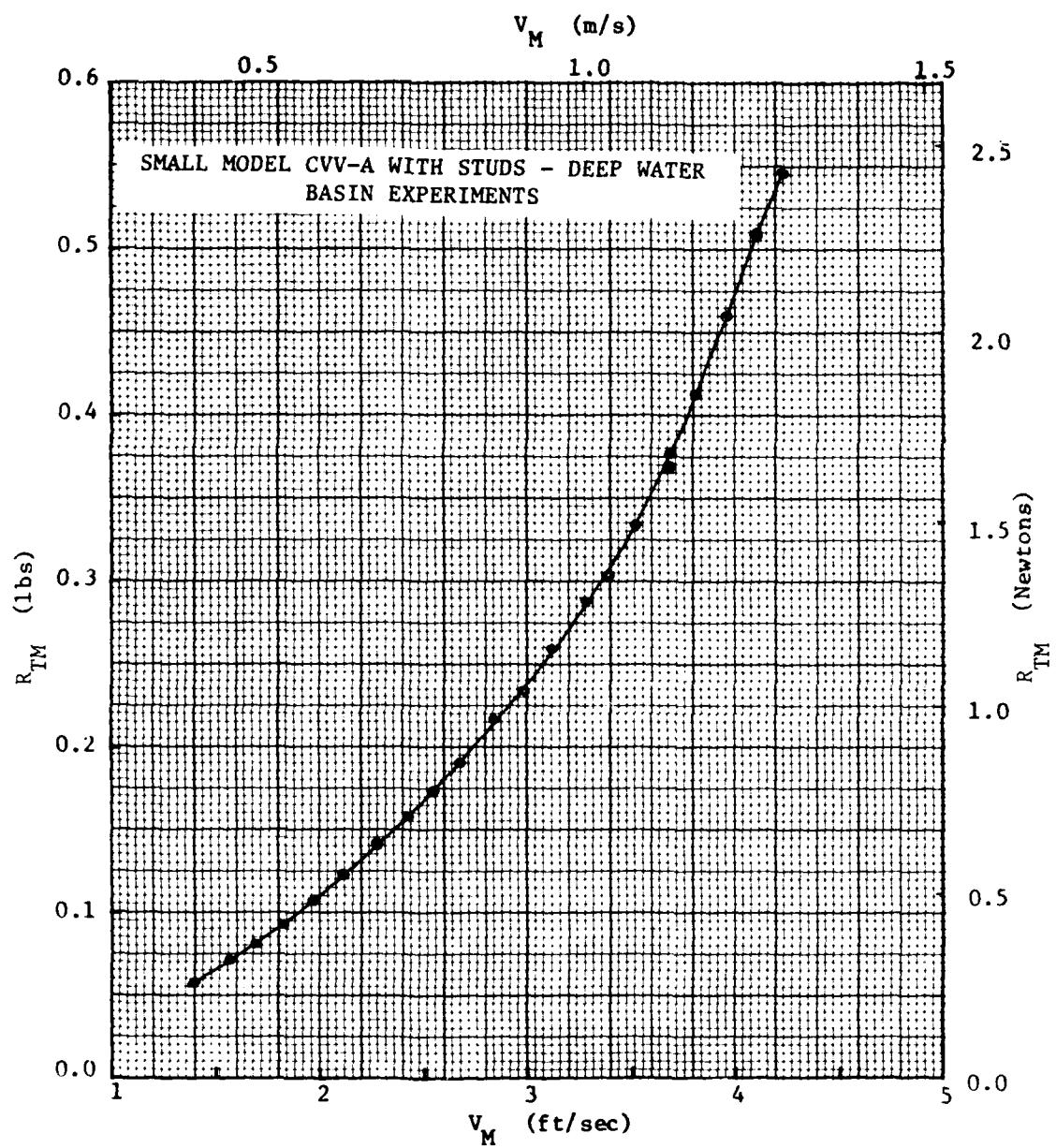


FIGURE A2 - RESISTANCE VALUES FOR THE SMALL CVV-A MODEL WITH STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

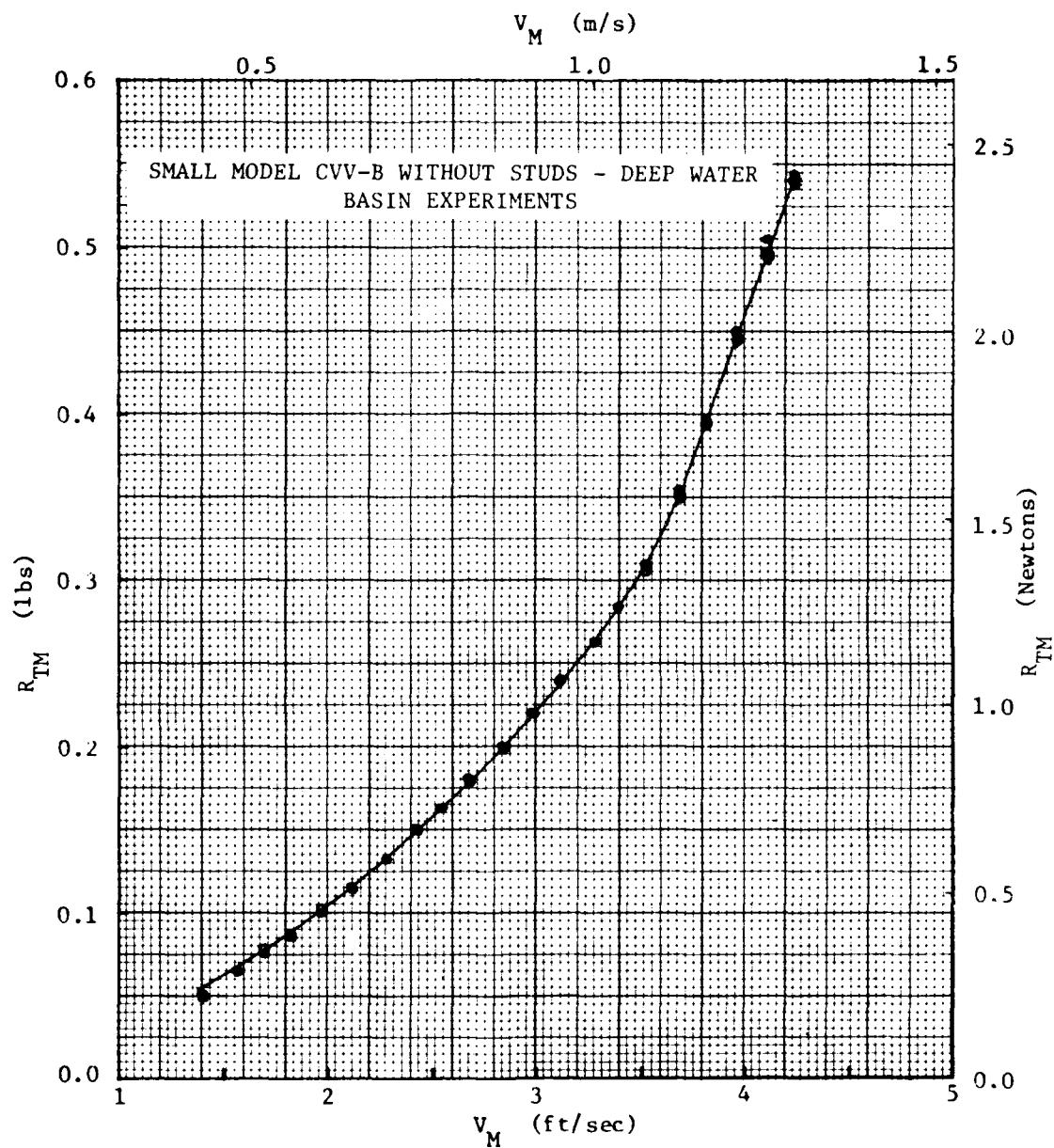


FIGURE A3 - RESISTANCE VALUES FOR THE SMALL CVV-B MODEL WITHOUT STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

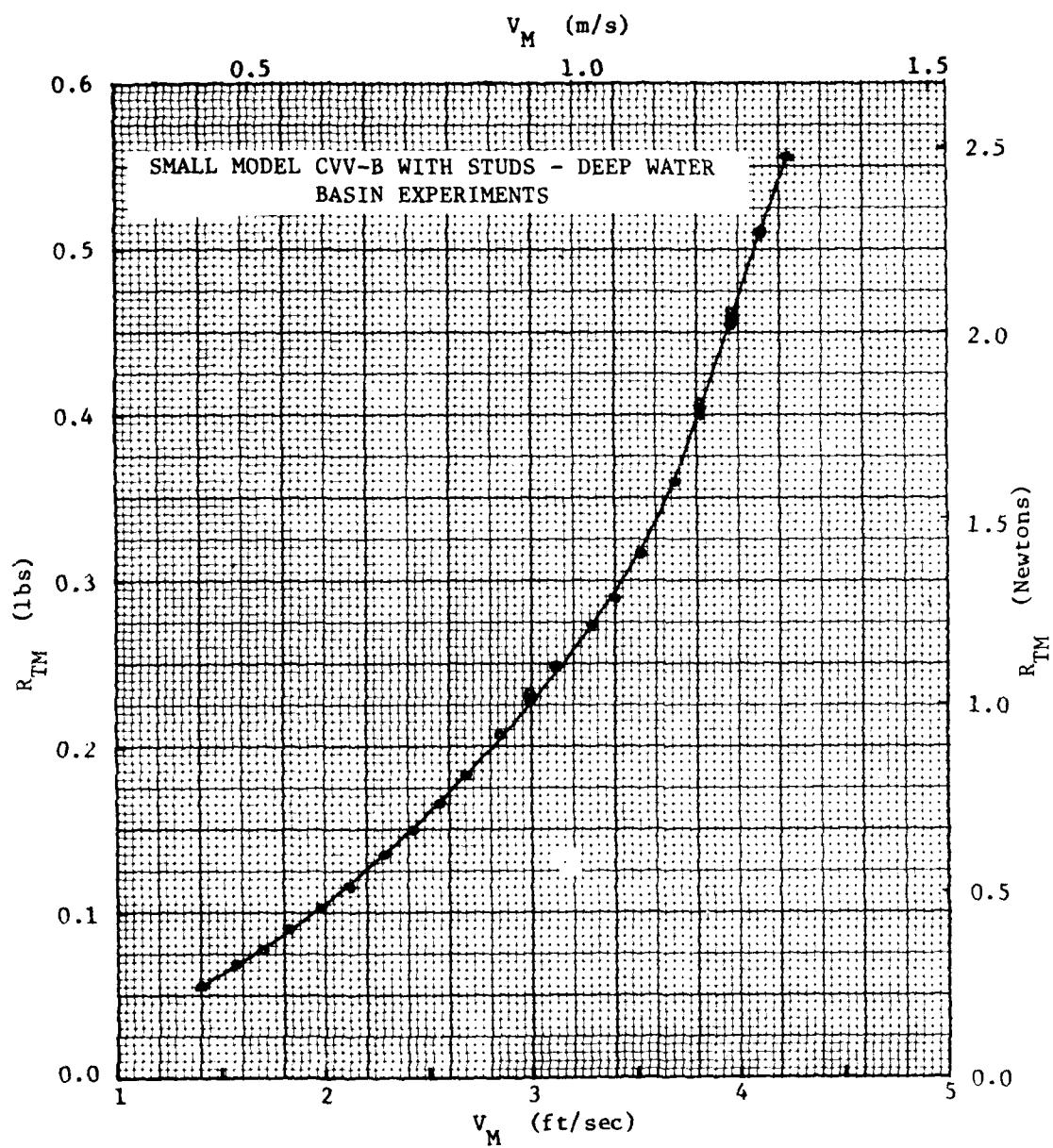


FIGURE A4 - RESISTANCE VALUES FOR THE SMALL CVV-B MODEL WITH STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

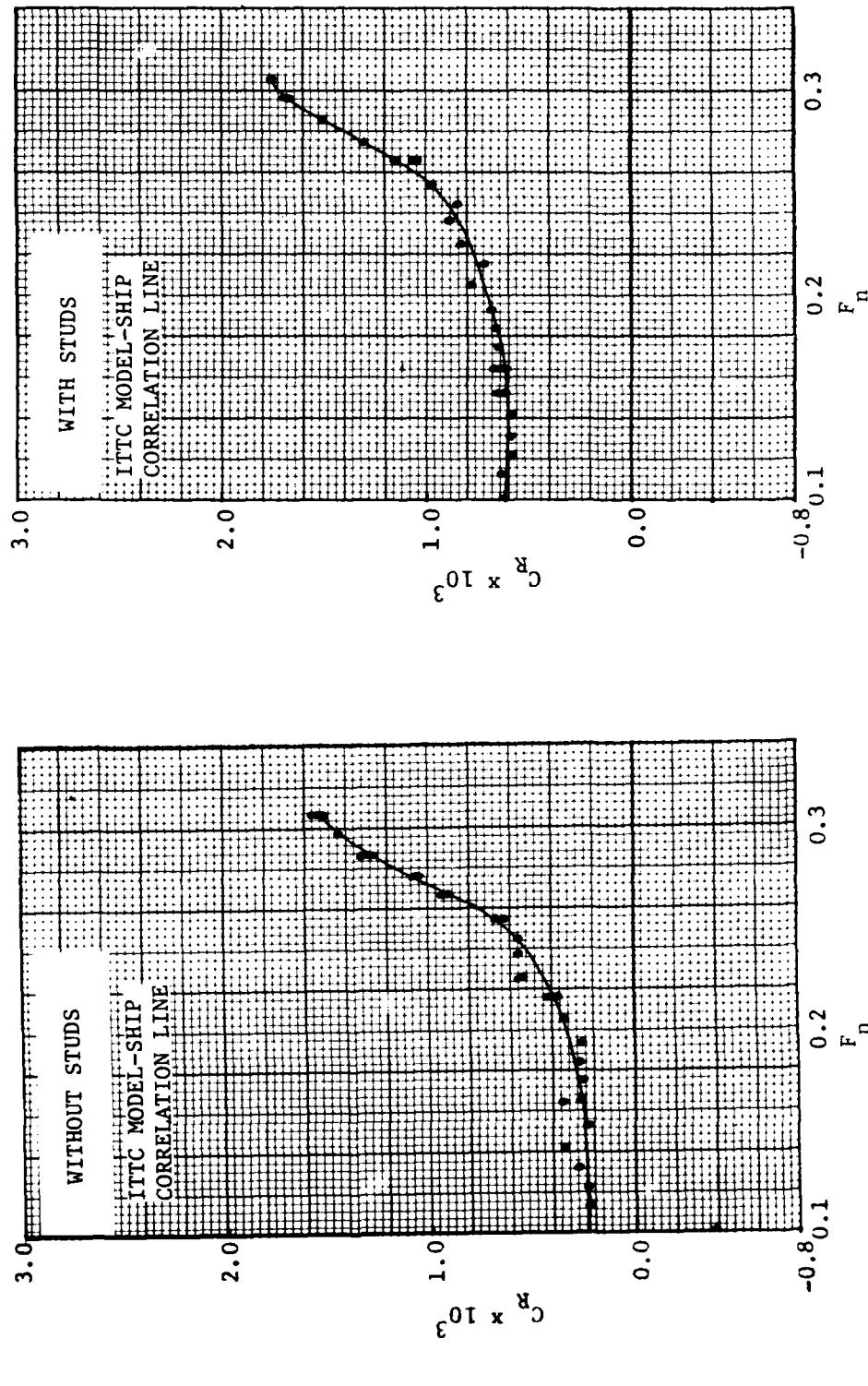


FIGURE A5 - RESIDUARY RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-A MODEL FROM THE DEEP WATER BASIN EXPERIMENTS

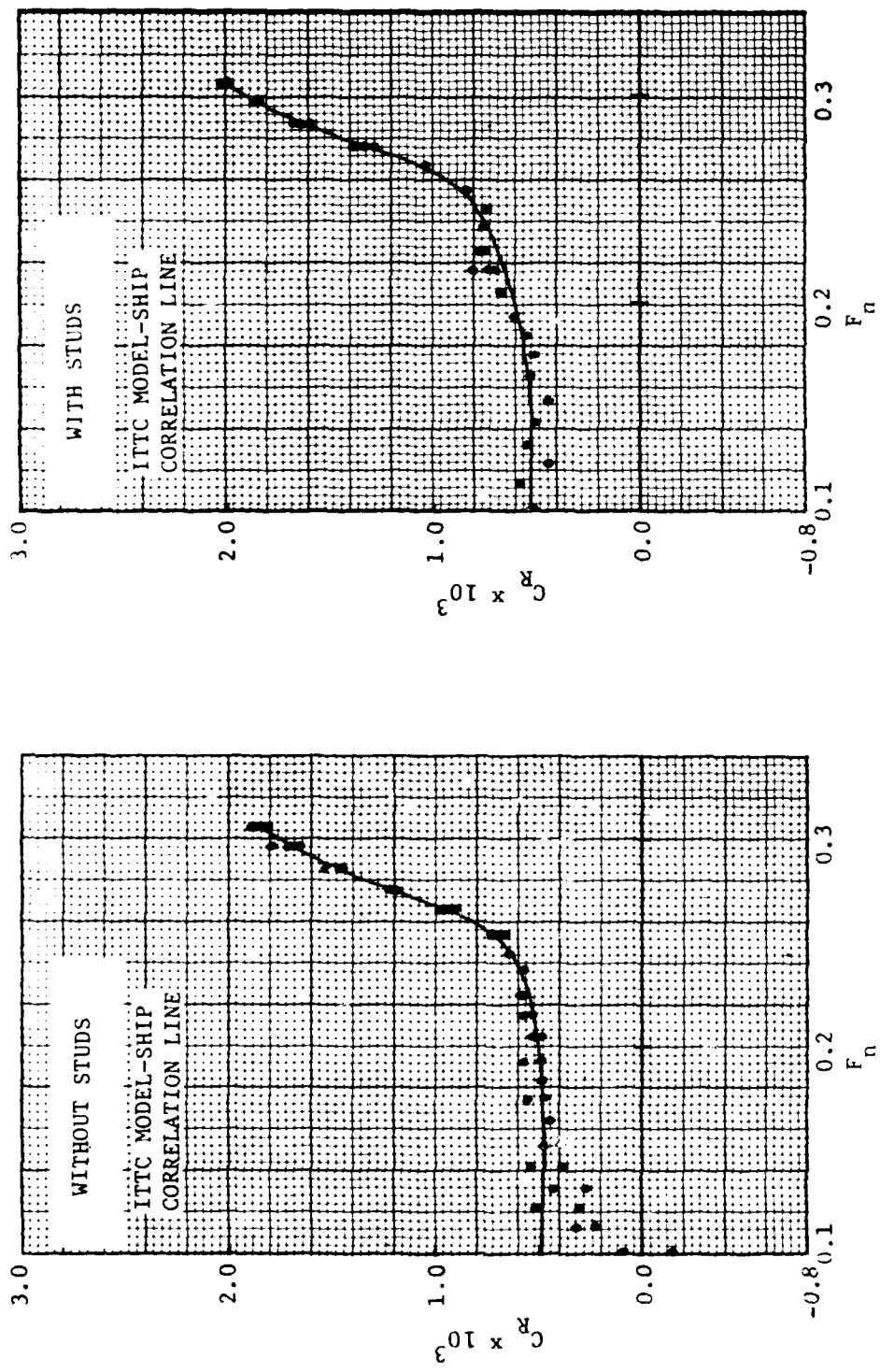


FIGURE A6 - RESIDUARY RESISTANCE COEFFICIENT CURVES FOR THE SMALL CVV-B MODEL FROM THE DEEP WATER BASIN EXPERIMENTS

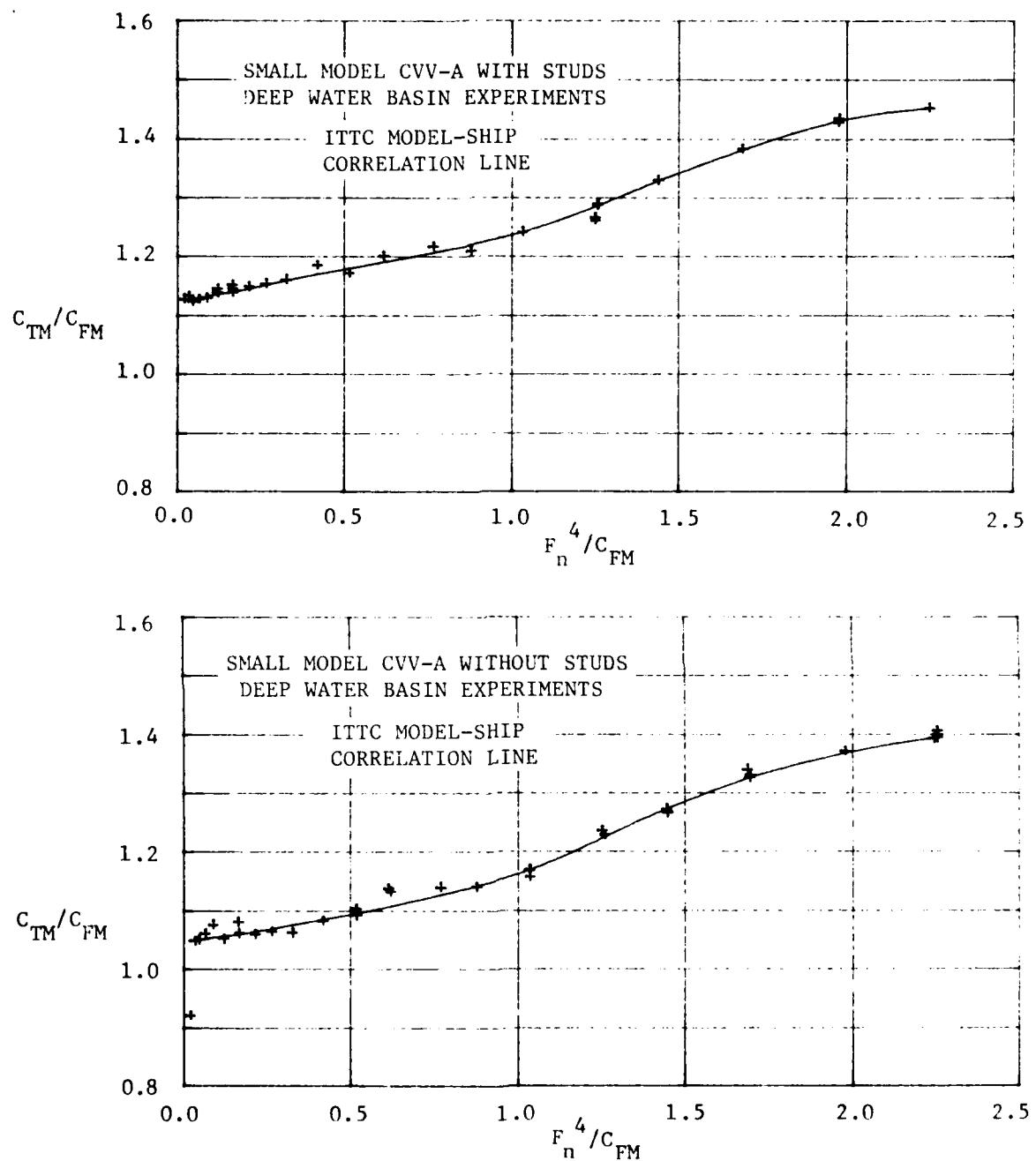


FIGURE A7 - PROHASKA PLOTS FOR THE SMALL CVV-A MODEL FROM THE DEEP WATER BASIN EXPERIMENTS

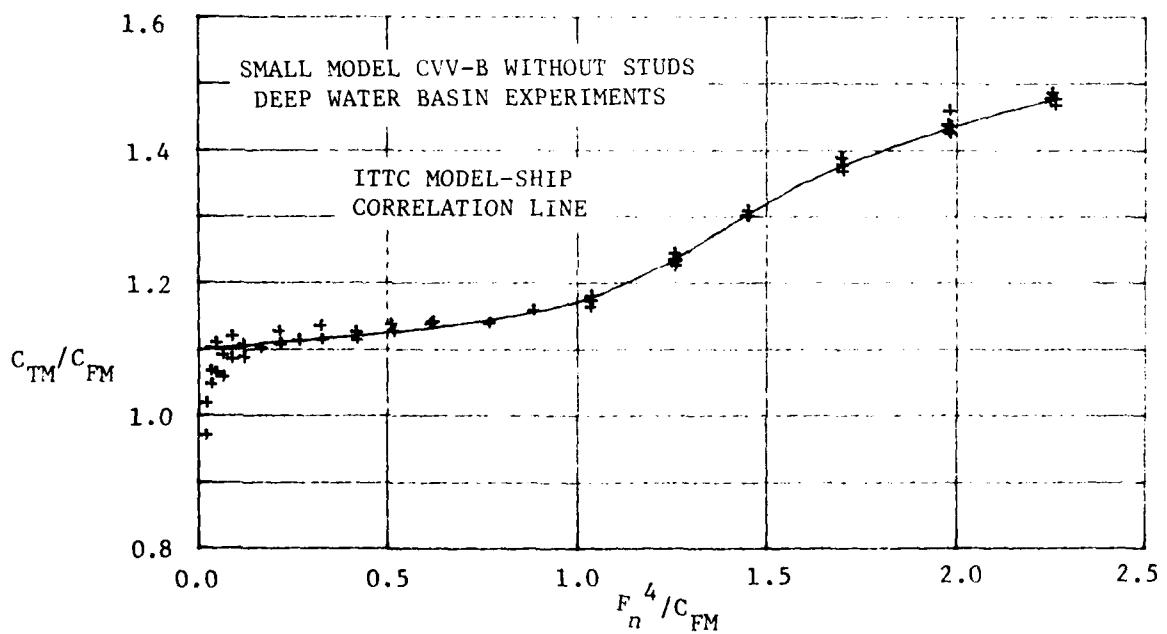
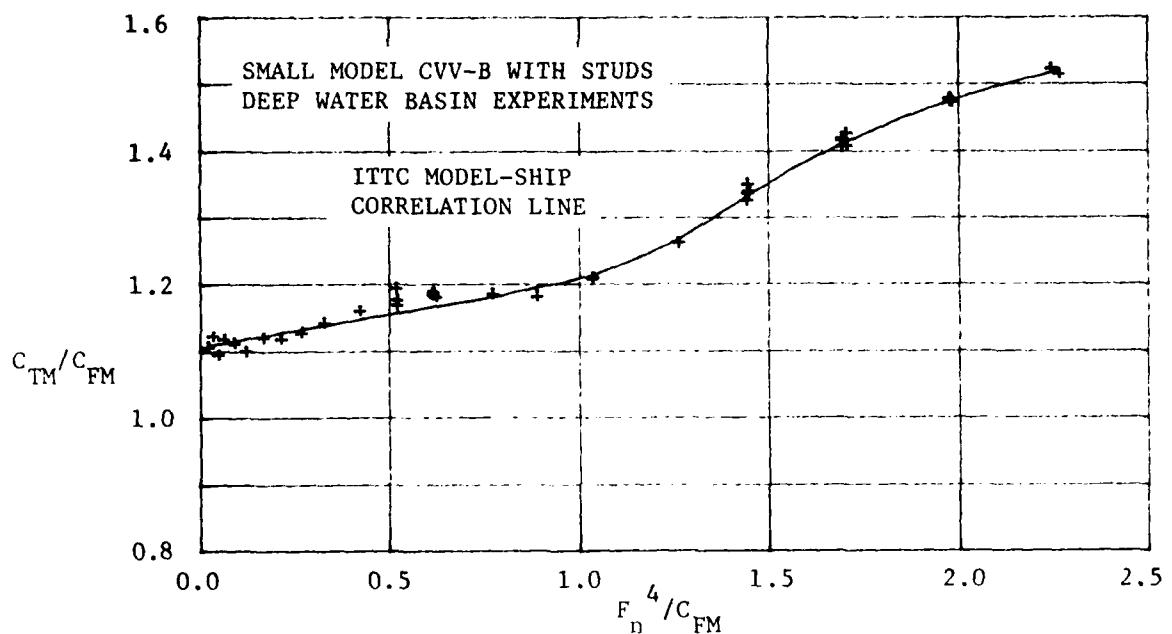


FIGURE A8 - PRO ASKA PLOTS FOR THE SMALL CVV-B MODEL FROM THE DEEP  
WATER BASIN EXPERIMENTS

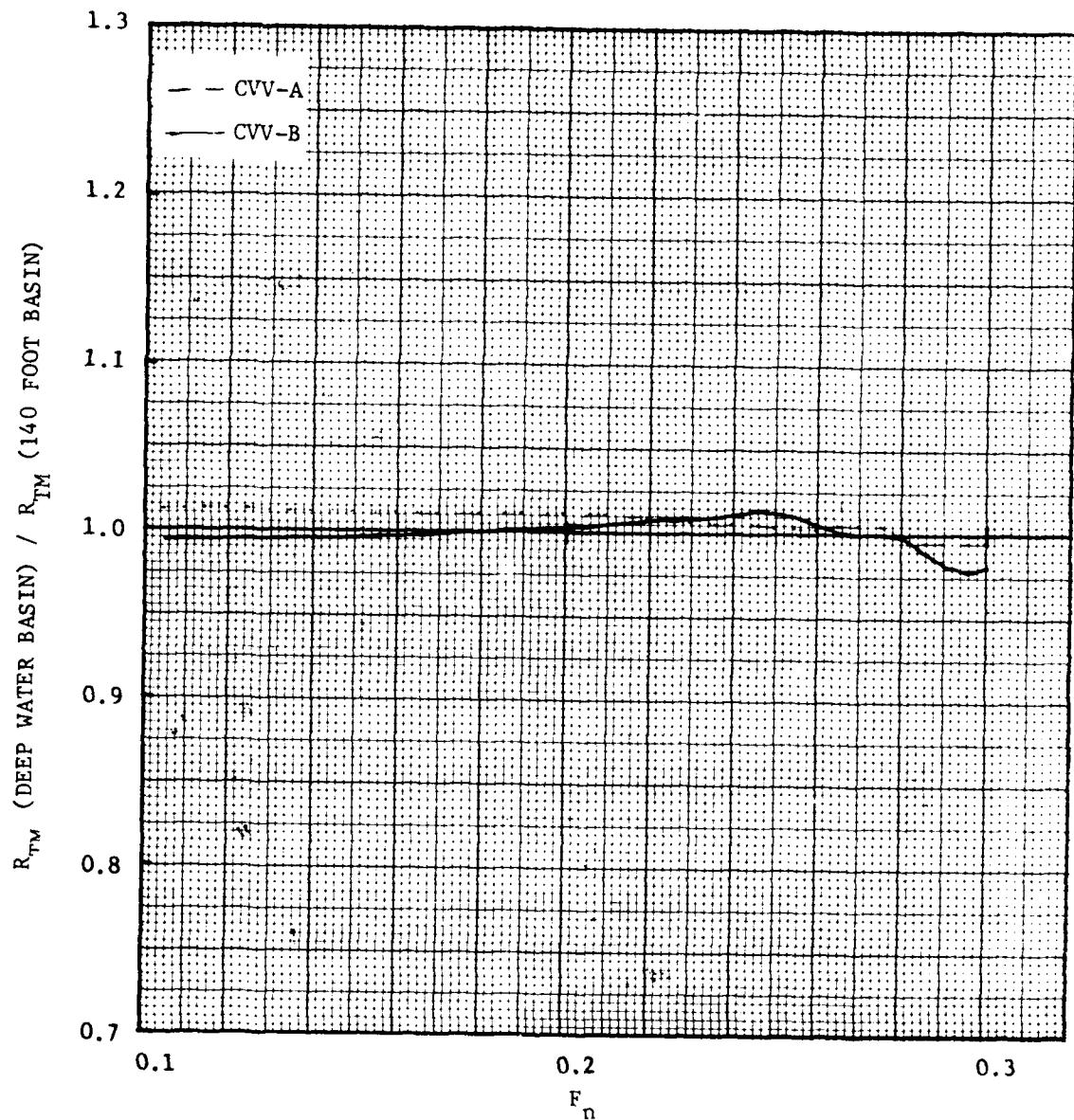


FIGURE A9 -  $R_{TM}$  (DEEP WATER BASIN) /  $R_{TM}$  (140 FOOT BASIN) FOR THE SMALL CVV-A AND CVV-B MODELS

TABLE A1 - UNIFORM RESISTANCE DATA FOR THE SMALL CUVVA MODEL WITHOUT STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

POINT NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES									
	1.820 M 5.97 FT		0.520 M 2 5.597 FT 2		DENSITY		997.4 KG/M <sup>3</sup>		1.9352 SLUGS FT <sup>3</sup>	
	WETTED SURFACE		FREQUENCIES		KINEMATIC		0.9307E-6 M <sup>2</sup> /S		1.0018E-5 FT <sup>2</sup> /S	
POINT NUMBER	VS (M/S)	VS (KNOTS)	VS (M/S)	VS (M/S)	VM (FT/SEC)	VM (FT/SEC)	RTM (N)	RTM (LBS)	CFM *1000	CFM *1000
1	0.101	5.10	9.91	0.425	1.394	0.210	0.047	4.492	-0.390	4.882
2	0.122	6.18	12.02	0.515	1.690	0.338	0.076	4.910	0.230	4.680
3	0.141	7.17	13.94	0.598	1.961	0.452	0.102	4.875	0.342	4.533
4	0.164	8.31	16.15	0.692	2.271	0.589	0.133	4.745	0.351	4.394
5	0.183	9.30	18.07	0.775	2.542	0.710	0.160	4.562	0.271	4.291
6	0.205	10.37	20.16	0.864	2.836	0.879	0.198	4.537	0.342	4.195
7	0.224	11.37	22.10	0.947	3.108	1.089	0.245	4.681	0.564	4.118
8	0.244	12.38	24.08	1.041	3.384	1.272	0.280	4.611	0.664	4.047
9	0.266	13.47	26.18	1.123	3.683	1.460	0.361	4.916	0.937	3.979
10	0.285	14.46	28.11	1.205	3.954	1.679	0.445	5.254	1.331	3.923
11	0.305	15.48	30.09	1.290	4.232	1.823	0.522	5.385	1.515	3.871
12	0.113	5.71	11.11	0.476	1.562	0.293	0.066	4.985	0.225	4.761
13	0.131	6.66	12.94	0.555	1.820	0.390	0.088	4.882	0.276	4.606
14	0.152	7.72	15.01	0.643	2.111	0.563	0.113	4.688	0.226	4.462
15	0.175	8.86	17.21	0.738	2.421	0.648	0.146	4.590	0.255	4.335
16	0.193	9.78	19.00	0.815	2.673	0.776	0.174	4.506	0.259	4.247
17	0.215	10.92	21.22	0.910	2.985	0.982	0.221	4.577	0.426	4.152
18	0.215	10.92	21.23	0.910	2.986	0.972	0.219	4.526	0.375	4.151
19	0.215	10.57	21.22	0.910	2.985	0.976	0.219	4.545	0.393	4.152
20	0.215	10.92	21.22	0.910	2.985	0.976	0.219	4.545	0.393	4.152
21	0.237	12.00	23.33	1.000	3.281	1.203	0.270	4.639	0.567	4.073
22	0.254	12.87	25.02	1.073	3.519	1.400	0.315	4.692	0.676	4.016
23	0.275	13.94	27.10	1.162	3.811	1.758	0.395	5.025	1.073	3.952
24	0.296	15.02	29.20	1.252	4.107	2.168	0.487	5.336	1.443	3.894
25	0.266	13.49	26.22	1.124	3.688	1.600	0.360	4.882	0.904	3.978
26	0.266	13.49	26.22	1.124	3.688	1.600	0.360	4.882	0.904	3.978
27	0.286	14.48	28.15	1.207	3.959	1.968	0.443	5.213	1.291	3.922
28	0.286	14.48	28.14	1.206	3.958	1.961	0.441	5.198	1.275	3.922
29	0.254	12.87	25.03	1.073	3.520	1.400	0.315	4.689	0.674	4.015
30	0.254	12.87	25.03	1.073	3.520	1.386	0.312	4.643	0.628	4.015
31	0.275	13.95	27.11	1.162	3.813	1.751	0.394	5.000	1.049	3.952
32	0.275	13.95	27.11	1.162	3.813	1.751	0.394	5.000	1.049	3.952
33	0.164	8.34	16.20	0.695	2.279	0.583	0.131	4.656	0.266	4.390
34	0.225	11.40	22.15	0.950	3.116	1.059	0.245	4.657	0.542	4.115
35	0.306	15.50	30.13	1.292	4.238	2.341	0.526	5.410	1.540	3.870
36	0.306	15.50	30.12	1.291	4.237	2.335	0.529	5.436	1.567	3.870
37	0.306	15.50	30.12	1.291	4.237	2.330	0.524	5.389	1.519	3.870

TABLE A2 - UNFAIRED RESISTANCE DATA FOR THE SMALL CUV-A MODEL WITH STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

POINT	FROUDE NUMBER	VS (M/S)	VS (KNOTS)	VS (M/S)	VM (FT/SEC)	VM (FT/SEC)	RTM (N)	RTM (LBS)	CTN * 1000	CR * 1000	CFM * 1000	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES
												LENGTH M
												5.97 FT
1	0.101	5.11	9.93	0.426	1.397	0.259	0.058	5.499	0.620	4.879		
2	0.122	6.19	12.02	0.515	1.691	0.362	0.081	5.255	0.575	4.679		
3	0.142	7.19	13.97	0.599	1.965	0.476	0.107	5.115	0.584	4.531		
4	0.164	8.32	16.17	0.693	2.275	0.631	0.142	5.060	0.668	4.392		
5	0.184	9.31	18.09	0.776	2.545	0.772	0.174	4.949	0.659	4.290		
6	0.205	10.38	20.18	0.865	2.839	0.965	0.217	4.971	0.777	4.195		
7	0.225	11.39	22.14	0.949	3.114	1.155	0.260	4.944	0.828	4.116		
8	0.244	12.38	24.07	1.032	3.386	1.351	0.304	4.893	0.846	4.047		
9	0.266	13.49	26.21	1.124	3.687	1.679	0.377	5.127	1.149	3.978		
10	0.266	13.48	26.21	1.123	3.686	1.675	0.377	5.119	1.141	3.978		
11	0.285	14.47	28.13	1.206	3.956	2.044	0.460	5.422	1.500	3.923		
12	0.113	5.72	11.11	0.476	1.563	0.317	0.071	5.389	0.629	4.760		
13	0.131	6.65	12.93	0.554	1.819	0.414	0.093	5.190	0.584	4.606		
14	0.152	7.72	15.00	0.643	2.110	0.548	0.123	5.111	0.648	4.462		
15	0.175	8.86	17.21	0.738	2.421	0.703	0.158	4.981	0.645	4.335		
16	0.193	9.78	19.00	0.815	2.673	0.848	0.191	4.927	0.680	4.247		
17	0.215	10.90	21.19	0.908	2.980	1.041	0.234	4.867	0.713	4.153		
18	0.236	11.99	23.30	0.999	3.277	1.282	0.288	4.957	0.884	4.074		
19	0.254	12.87	25.01	1.072	3.518	1.486	0.334	4.984	0.968	4.016		
20	0.275	13.92	27.07	1.160	3.807	1.834	0.412	5.253	1.300	3.953		
21	0.296	15.02	29.20	1.252	4.107	2.268	0.510	5.582	1.689	3.894		
22	0.296	15.02	29.19	1.252	4.106	2.258	0.508	5.560	1.666	3.894		
23	0.305	15.49	30.10	1.291	4.234	2.427	0.546	5.620	1.750	3.870		
24	0.152	7.72	15.01	0.643	2.111	0.545	0.122	5.074	0.612	4.462		
25	0.152	7.72	15.00	0.643	2.110	0.545	0.122	5.079	0.616	4.462		
26	0.164	8.32	16.13	0.694	2.276	0.627	0.141	5.028	0.636	4.392		
27	0.164	8.32	16.18	0.694	2.276	0.624	0.140	5.000	0.608	4.392		
28	0.266	13.47	26.18	1.122	3.682	1.644	0.370	5.035	1.056	3.979		
29	0.266	13.46	26.17	1.122	3.681	1.637	0.368	5.017	1.037	3.979		

TABLE A-3 - UNFAIR RESTRAINT DATA FOR THE SMALL CIV-B "GOE" PROJECT

POINT	FREUDENBERG NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES				CFM * 1000
		LENGTH WETTED SURFACE	VS (M/S)	VS (KNOTS)	VM (M/S)	
		1.820 0.505 M-2	5.37 5.436 FT-2	997.4 0.9307E-6 KG/M <sup>3</sup>	1.9352 1.0018E-5 SLUGS FT <sup>3</sup> /FT <sup>2</sup> S	
1	0.101	5.12	9.95	0.426	1.399	0.228
2	0.122	6.19	12.04	0.516	1.693	0.348
3	0.142	7.19	13.98	0.599	1.966	0.458
4	0.164	8.32	16.18	0.694	2.276	0.586
5	0.184	9.31	18.10	0.776	2.546	0.724
6	0.205	10.38	20.17	0.865	2.837	0.889
7	0.225	11.40	22.16	0.950	3.117	1.069
8	0.245	12.41	24.12	1.034	3.392	1.252
9	0.266	13.49	26.21	1.124	3.667	1.562
10	0.286	14.49	28.16	1.207	3.961	1.939
11	0.286	14.48	28.15	1.207	3.960	1.939
12	0.306	15.49	30.12	1.291	4.236	2.416
13	0.305	15.49	30.10	1.291	4.234	2.399
14	0.113	5.71	11.10	0.476	1.561	0.290
15	0.131	6.65	12.93	0.554	1.819	0.390
16	0.152	7.71	14.99	0.643	2.109	0.514
17	0.174	8.84	17.19	0.737	2.418	0.659
18	0.192	9.76	18.97	0.813	2.668	0.803
19	0.215	10.88	21.15	0.907	2.975	0.979
20	0.275	13.95	27.12	1.163	3.814	1.762
21	0.296	15.03	29.21	1.252	4.108	2.244
22	0.296	15.02	29.19	1.252	4.106	2.210
23	0.237	12.00	23.32	1.009	3.280	1.169
24	0.254	12.88	25.03	1.073	3.521	1.375
25	0.266	13.49	26.23	1.124	3.669	1.569
26	0.266	13.49	26.22	1.124	3.688	1.551
27	0.101	5.12	9.96	0.427	1.401	0.217
28	0.122	6.20	12.04	0.516	1.694	0.334
29	0.142	7.19	13.98	0.599	1.966	0.445
30	0.164	8.32	16.18	0.694	2.276	0.586
31	0.184	9.31	18.09	0.776	2.545	0.724
32	0.205	10.39	20.19	0.866	2.840	0.882
33	0.224	11.38	22.11	0.948	3.110	1.062
34	0.245	12.41	24.12	1.034	3.392	1.252
35	0.266	13.48	26.21	1.123	3.686	1.575
36	0.266	13.48	26.20	1.123	3.685	1.562
37	0.286	14.49	28.17	1.208	3.962	1.972
38	0.286	14.49	28.17	1.208	3.962	1.936
39	0.306	15.51	30.15	1.292	4.240	2.406
40	0.306	15.51	30.15	1.292	4.240	2.394
41	0.254	12.57	25.03	1.073	3.520	1.355
42	0.275	13.75	27.13	1.153	3.816	1.751
43	0.297	15.03	29.23	1.253	4.110	2.249
44	0.297	15.03	29.22	1.253	4.110	2.249
45	0.113	5.71	11.10	0.476	1.561	0.290

TABLE A3 - UNFAIRED RESISTANCE DATA FOR THE SMALL CVV-B MODEL WITHOUT STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

(CONTINUED)

POINT	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR. CFM VALUES			1.9352 SLUGS/FT <sup>2</sup> /S 0.9307E-6 M <sup>2</sup> /S 1.0018E-5 FT <sup>-2</sup> /S	
	LENGTH WETTED	M	5.97 FT <sup>2</sup>		
			DENSITY KINEMATIC VISCOSITY		
POINT	FRONDE NUMBER	VS (M/S)	VS (KNOTS)	VM (N/S)	VM (FT/SEC)
46	0.132	6.67	12.97	0.556	1.824
47	0.152	7.73	15.02	0.554	2.113
48	0.175	8.88	17.26	0.740	2.427
49	0.193	9.79	15.33	0.816	2.675
50	0.215	10.62	21.22	0.910	2.955
51	0.237	12.00	23.32	1.000	3.280
52	0.254	12.69	25.05	1.074	3.523
53	0.275	13.94	27.10	1.162	3.812
54	0.296	15.03	29.21	1.252	4.108

TABLE A4 - UNPUBLISHED RESISTANCE DATA FOR THE SMALL CUV-B MODEL WITH STUDS FROM THE DEEP WATER BASIN EXPERIMENTS

POINT	LENGTH WETTED SURFACE FRONDE NUMBER	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES			DENSITY 997.4 KG/M <sup>3</sup>	KINEMATIC 0.9307E-6 M <sup>-2</sup> /S	1.9352 SLUGS/FT <sup>-3</sup> 1.0018E-5 FT <sup>-2</sup> /S	
		VS (M/S)	VS (KNOTS)	VM (M/S)	VM (FT/SEC)	RTM (N)	RTM (LBS)	CFM *1000
1	0.101	5.13	9.97	0.427	1.402	0.248	0.056	5.397
2	0.122	6.21	12.07	0.517	1.697	0.345	0.178	5.116
3	0.142	7.22	14.03	0.601	1.973	0.458	0.103	5.034
4	0.165	8.35	16.23	0.696	2.283	0.600	0.135	4.59
5	0.184	9.34	18.15	0.778	2.553	0.738	0.166	4.838
6	0.205	10.40	20.21	0.867	2.843	0.920	0.207	4.867
7	0.225	11.40	22.17	0.950	3.118	1.107	0.249	4.865
8	0.245	12.41	24.13	1.034	3.394	1.289	0.290	4.784
9	0.266	13.50	26.24	1.125	3.690	1.600	0.350	5.021
10	0.286	14.50	28.18	1.208	3.964	2.058	0.463	5.598
11	0.286	14.50	28.19	1.209	3.965	2.030	0.456	5.520
12	0.306	15.52	30.16	1.293	4.242	2.468	0.555	5.863
13	0.113	5.73	11.14	0.478	1.567	0.307	0.069	5.340
14	0.131	6.66	12.95	0.555	1.822	0.400	0.090	5.149
15	0.153	7.74	15.04	0.645	2.116	0.514	0.115	4.903
16	0.175	8.86	17.22	0.738	2.422	0.665	0.150	4.848
17	0.193	9.79	19.03	0.816	2.677	0.814	0.183	4.852
18	0.215	10.92	21.22	0.910	2.985	1.034	0.233	4.961
19	0.237	12.01	23.34	1.001	3.283	1.217	0.274	4.826
20	0.254	12.87	25.03	1.073	3.520	1.410	0.317	4.864
21	0.254	12.67	25.03	1.073	3.520	1.406	0.316	4.852
22	0.275	13.94	27.09	1.161	3.810	1.813	0.408	5.339
23	0.275	13.94	27.09	1.161	3.810	1.779	0.400	5.238
24	0.296	15.03	29.21	1.252	4.108	2.268	0.510	5.745
25	0.296	15.03	29.21	1.252	4.108	2.265	0.509	5.736
26	0.216	10.93	21.24	0.911	2.988	1.020	0.229	4.885
27	0.216	10.93	21.24	0.911	2.988	1.013	0.228	4.852
28	0.275	13.34	27.10	1.162	3.812	1.799	0.405	5.293
29	0.275	13.34	27.10	1.162	3.812	1.796	0.404	5.223
30	0.296	14.48	28.14	1.206	3.958	2.041	0.458	5.568
31	0.285	14.47	28.13	1.206	3.957	2.020	0.454	5.514
32	0.296	15.02	29.20	1.252	4.107	2.272	0.511	5.757
33	0.296	15.02	29.19	1.252	4.106	2.265	0.509	5.742
34	0.286	14.48	28.15	1.207	3.959	2.037	0.458	5.556
35	0.286	14.48	28.14	1.206	3.958	2.037	0.458	5.559
36	0.296	15.02	29.19	1.252	4.106	2.272	0.511	5.759
37	0.224	11.37	22.10	0.948	3.109	1.107	0.249	4.893
38	0.224	11.37	22.10	0.947	3.108	1.103	0.248	4.881
39	0.305	15.45	30.10	1.290	4.233	2.472	0.556	5.896
40	0.305	15.48	30.10	1.290	4.233	2.472	0.556	5.896

TABLE 45 - UNWATERED RESISTANCE DATA FOR THE SMALL CVV-D MODEL WITHOUT STUDS FROM THE DEE WATER BASIN EXPERIMENTS

POINT	FRUDE NUMBER	LTTC MODEL-SHP CORRELATION LINE USED			FCR CR, CFM VALUES	1.9352 SLUGS/FT <sup>3</sup>	1.0018E-5 FT <sup>2</sup> /S			
		LENGTH M	WETTED M <sup>2</sup>	5.97 FT						
1	0.101	5.11	9.93	0.426	1.396	0.228	0.051			
2	0.122	6.19	12.02	0.515	1.691	0.341	0.077			
3	0.142	7.16	13.96	0.549	1.964	0.445	0.100			
4	0.161	8.32	16.18	0.614	2.276	0.576	0.129			
5	0.184	9.32	18.12	0.777	2.548	0.679	0.153			
6	0.205	10.33	20.18	0.855	2.839	0.841	0.189			
7	0.224	11.38	22.12	0.948	3.111	1.027	0.231			
8	0.244	12.37	24.08	1.012	3.207	1.244	0.277			
9	0.265	13.47	26.19	1.123	3.684	1.541	0.346			
10	0.285	14.47	28.13	1.206	3.957	1.979	0.445			
11	0.113	5.71	11.11	0.476	1.562	0.233	0.064			
12	0.131	6.66	12.95	0.555	1.821	0.383	0.086			
13	0.152	7.72	15.01	0.643	2.111	0.500	0.112			
14	0.175	8.26	17.21	0.738	2.421	0.627	0.141			
15	0.193	9.79	19.03	0.816	2.676	0.748	0.168			
16	0.215	10.91	21.21	0.909	2.983	0.914	0.205			
17	0.237	12.00	23.32	1.000	3.280	1.151	0.259			
18	0.254	12.87	25.02	1.073	3.519	1.365	0.307			
19	0.275	13.93	27.08	1.161	3.809	1.765	0.397			
20	0.296	15.03	29.21	1.252	4.109	2.268	0.510			
21	0.296	15.03	29.21	1.252	4.108	2.261	0.508			
22	0.306	15.49	30.11	1.291	4.235	2.430	0.546			
23	0.254	12.87	25.02	1.073	3.519	1.362	0.306			
24	0.254	12.87	25.02	1.073	3.519	1.365	0.307			
25	0.266	13.46	26.20	1.123	3.635	1.558	0.350			
26	0.256	13.46	26.20	1.123	3.635	1.551	0.349			
27	0.215	10.91	21.21	0.909	2.983	0.951	0.214			
28	0.215	13.93	27.08	1.161	3.809	1.765	0.398			
29	0.275	13.93	27.08	1.161	3.809	1.755	0.394			
30	0.275	13.93	27.08	1.161	3.809	1.755	0.394			

TABLE 46 - UNIFORMED REYNOLDS NUMBER STUDS FROM EXPERIMENTS

POINT	FROUDE NUMBER	VS (M/S)	(KNOTS)	VS (M/S)	(KNOTS)	VS (M/S)	(KNOTS)	ITTC MODEL-SHIP CORRELATION LINE USED FOR CR, CFM VALUES			CR	CFM
								WETTED LENGTH	WETTED SURFACE	WETTED AREA		
1	0.101	5.14	10.00	0.429	1.406	0.255	0.057	5.438	0.565	4.873		
2	0.123	6.22	12.09	0.518	1.700	0.355	0.080	5.177	0.503	4.771		
3	0.142	7.22	14.03	0.601	1.973	0.465	0.105	5.034	0.311	4.674		
4	0.165	8.35	16.23	0.696	2.283	0.607	0.136	4.455	0.316	4.574		
5	0.184	9.34	18.16	0.778	2.554	0.781	0.169	4.155	0.367	4.267		
6	0.205	10.42	20.25	0.868	2.848	0.917	0.206	3.714	0.372	4.192		
7	0.225	11.41	22.18	0.951	3.120	1.110	0.250	4.805	0.620	4.114		
8	0.245	12.41	24.13	1.034	3.394	1.313	0.295	4.804	0.760	4.045		
9	0.266	13.50	26.24	1.125	3.691	1.665	0.374	5.150	1.173	3.977		
10	0.286	14.49	28.16	1.207	3.961	1.117	0.476	5.095	1.763	3.922		
11	0.113	5.73	11.13	0.477	1.560	0.510	0.070	5.331	0.573	4.758		
12	C.132	6.67	12.36	0.556	1.823	0.403	0.091	5.114	0.510	4.604		
13	0.153	7.73	15.03	0.644	2.114	0.527	0.119	4.973	0.512	4.461		
14	0.175	8.86	17.21	0.739	2.421	0.672	0.151	4.833	0.497	4.335		
15	0.193	9.79	19.63	0.836	2.660	0.826	0.184	4.828	0.582	4.246		
16	0.215	10.92	21.23	0.910	2.986	1.007	0.226	4.757	0.606	4.151		
17	0.237	12.01	23.34	1.001	3.283	1.227	0.276	4.798	0.726	4.072		
18	0.254	12.87	25.02	1.073	3.519	1.434	0.322	4.880	0.864	4.016		
19	0.275	13.95	27.12	1.163	3.814	1.868	0.420	5.412	1.461	3.951		
20	0.297	15.04	29.24	1.253	4.112	2.379	0.535	5.928	2.035	3.893		
21	0.297	15.04	29.23	1.253	4.111	2.368	0.532	5.905	2.012	3.893		
22	0.306	15.49	30.12	1.251	4.236	2.551	0.574	5.990	2.121	3.870		
23	0.306	15.49	30.11	1.291	4.235	2.547	0.573	5.955	2.115	3.870		
24	0.266	13.49	26.23	1.124	3.669	1.628	0.375	5.166	1.188	3.978		
25	0.266	13.49	26.22	1.124	3.688	1.658	0.373	5.137	1.159	3.978		
26	0.275	13.92	27.08	1.161	3.809	1.858	0.418	5.396	1.444	3.952		
27	0.275	13.13	27.07	1.161	3.808	1.855	0.417	5.389	1.437	3.953		
28	0.254	12.87	25.02	1.073	3.519	1.444	0.325	4.915	0.899	4.016		
29	0.254	12.87	25.02	1.073	3.519	1.437	0.323	4.891	0.876	4.016		
30	0.254	12.87	25.01	1.072	3.518	1.434	0.322	4.882	0.867	4.016		
31	0.254	12.87	25.01	1.072	3.512	1.434	0.322	4.882	0.867	4.016		
32	0.254	12.86	25.01	1.072	3.517	1.427	0.321	4.862	0.846	4.016		

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.
2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.
3. TECHNICAL MEMORANDA, AN INFORMAL SERIES, CONTAIN TECHNICAL DOCUMENTATION OF LIMITED USE AND INTEREST. THEY ARE PRIMARILY WORKING PAPERS INTENDED FOR INTERNAL USE. THEY CARRY AN IDENTIFYING NUMBER WHICH INDICATES THEIR TYPE AND THE NUMERICAL CODE OF THE ORIGINATING DEPARTMENT. ANY DISTRIBUTION OUTSIDE DTNSRDC MUST BE APPROVED BY THE HEAD OF THE ORIGINATING DEPARTMENT ON A CASE-BY-CASE BASIS.

